TEXTILE RESEARCH

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The Editor's Page

W. H. TURNER, in charge of the market research division of Marshall, Field & Co., New York, N. Y., has succeeded E. K. Mitchel as a member of U. S. Institute's Committee on Economic Research, Mr. Mitchel having resigned because he is no longer identified with the textile industry.

IN his preliminary study and discussion of the mechanical forces involved in pebble formation in rayon crêpe, R. L. Steinberger, a Textile Foundation Fellow, working under Prof. Bridgman, Physics Laboratory, Harvard University, has performed a valuable service for the industry and for the joint committee of the A. A. T. C. C. and the Throwsters Research Institute that is conducting experimental research on rayon crêping under a Textile Foundation grant. Not only has Mr. Steinberger clearly defined the physical factors involved and indicated the character of additional basic research that should be pursued, but has also confirmed the correctness of the research policy of the joint committee. In encouraging Mr. Steinberger to conduct this fundamental study U. S. Institute's Research Council has performed another useful service in connection with the joint committee's work.

THE large and representative attendance of all branches of the industry at U. S. Institute's conference on textile drying, and the unusual interest shown in the papers and discussion were not needed to confirm the prior conclusion of the Research Council that scientific study of certain of the basic problems of drying could not fail to produce valuable results of practical application. Now that their prior conclusion has been confirmed by a practically unanimous vote of this representative cross-section of the industry, U. S. Institute is obligated to attempt the organization of this study, or series of studies, and the co-operating financing of the research. A prospectus outlining tentatively the subjects to be investigated, the plans for the research as far as decided upon, the probable cost per co-operator, etc., has been prepared and may be obtained by addressing the Secretary. Further details will be acted upon at meetings of the Executive Committee and the Research Council to be held in New York City, June 3.

UNFORTUNATELY, it is impractical to publish in this magizine, or in any future issue, the complete stenographic report of the drying conference discussion. While the principles of drying, and particularly of air drying, were covered very completely in the papers read at the morning session, as published in this issue, it was in the afternoon discussion that practical drying problems, and the dyeing and finishing troubles incident thereto, were frankly talked about and analyzed. The discussion also emphasized the complicated nature of the problems, the fact that they are chemical as well as physical, and that for critical drying conditions that seriously damage the materials there is a serious lack of authoritative information. The stenographic report of the discussion in mimeographed form has been mailed to those who registered to receive it, and duplicates can be had at $1.00 a copy by addressing the Secretary. It is planned, however, to publish a brief outline report of the discussion in the July number.

"Production and Distribution Organization in the Textile Industry" to be Studied

AMONG the additional avenues of textile research of an economic and scientific character that are to be explored, as a result of recent appropriations made available by the Textile Foundation, is a study on "Production and Distribution Organization in the Textile Industry—A Study of Trends." The study will be conducted under the supervision of the Committee on Economic Research of U. S. Institute for Textile Research, which recommended the subject to the Foundation. This committee will select an agency for the active conduct of the work and for the compilation of reports. The project has the endorsement, and the committee during the progress of the study will have the co-operation in an advisory capacity, of the following textile association presidents: Arthur Besse, National Association of Wool Manufacturers and Associated Wool Industries; Dr. Claudius Murchison, Cotton-Textile Institute; W. Ray Bell, Association of Cotton Textile Merchants; Peter Van Horn, National Federation of Textiles.

Conduct of Study

The Textile Foundation has previously financed several investigations into distribution policies and methods in specific branches of the textile industry, and is now sponsoring a comprehensive survey of importance to the whole industry. Prior to securing the endorsement of its plans by association executives, and prior to their presentation to the Foundation, U. S. Institute's Committee on Economic Research had given the subject intensive study for a long period. At no time had there been any doubt in their minds as to the need of such a study; their problem was to plan it in such a manner that it would prove resultful when approached and conducted by men who combine a practical outlook with broad vision and without preconceived ideas, with the ability to analyze and properly to weigh facts and trends, and who will command the confidence of the industry and have the prestige to obtain access to the needed information.

Purpose and Scope

The purpose and scope of the study is outlined in the following memorandum presented to the Textile Foundation by the Committee on Economic Research: "It is recommended that a case study be undertaken of significant developments in the organization of textile production and marketing. This would involve, particularly, investigation into the factors affecting the success or failure of various types of organization which have undertaken, at any important point, to bridge the gap between mill and consumer. By this is meant, not only the extension of financial control over additional steps or functions, but also developments which have been effective in bringing into closer co-ordination the production and marketing

operations in the textile industry. The study would be based, not on theoretical considerations, but on the actual experience of a number of companies, both within and outside the textile industry.

"There are many important examples of such developments: mills which manufacture garments, garment manufacturers who have bought mills or who control retail stores, wholesalers who convert their own goods, mills or converters who have worked out close co-operative arrangements with wholesale or retail distributors, etc. Some appear to have succeeded; some have not. It is important for the textile industry to learn of the causes of failure as well as of the conditions of success. In the last analysis, each company in the textile industry must decide on the policy best suited to its own situation. But it would be of great value to companies, small as well as large, to have a groundwork of facts, based on an unbiased survey, to guide them in more intelligently dealing with their own situation."

Economic Research Committee

The Committee on Economic Research of U. S. Institute which will supervise this study, and which was responsible for initiating the idea and the tentative plans, is as follows: F. S. Blanchard, Chairman; Paul T. Cherington, Stanley B. Hunt, W. H. Turner, H. V. R. Scheel, D. G. Woolf and A. W. Zelomek.

Textile Foundation Directors

The directors of the Textile Foundation, who approved this study and whose financing has made its conduct possible, are as follows: Chairman, Franklin W. Hobbs, president Arlington Mills, Boston, Mass.; treasurer, Stuart W. Cramer, president Cramerton Mills, Inc., Cramerton, N. C.; Frank D. Cheney, Cheney Bros., New York, N. Y.; the Secretary of Agriculture and the Secretary of Commerce.

Textile Foundation Research

IN addition to providing the financing for the study of "Production and Distribution Organization in the Textile Industry," noted elsewhere in this issue, the Textile Foundation, at a recent meeting of its directors, authorized appropriations for the extension of a number of researches previously in progress. Four research fellows whose terms expire during the spring or summer were reappointed for a period of one year to continue research work on textile fibres. The Foundation recently issued a list describing about 50 progress reports of its group of research fellows. A copy of this descriptive list may be obtained upon application to the Foundation in Washington.

Funds were allocated for the continuation and extension of the following projects: Fundamental Study of Vat Printing Pastes; The Effects of Oxidizing and Reducing Agents on Wool; a further study of The Chemistry of Wool Fibres; The Quantitative Determination of Fibres in Mixtures;

The Determination of Oil, Soap and Other Extraneous Material in Wool and Various Stages of Wool Processing. This work is to be continued under the supervision of the American Association of Textile Chemists and Colorists.

Textile Waste Treatment

Some months ago a survey of textile waste treatment and recovery was initiated and a compilation of fundamental and widely applicable information is now being prepared for publication. During the course of this survey it became apparent that little fundamental research on this important problem had been undertaken, and upon recommendation of those who conducted the survey and an advisory committee of a number of the country's leading authorities on waste disposal, the Foundation is about to undertake fundamental research on The Colloidal and Electric Nature of the Polluting Substances Carried in Textile Wastes, and investigate means for removing these substances from the wastes.

In addition to this type of research, small plant scale work will be carried out to develop the practical applications of the laboratory findings and conduct research on the problem of refining municipal sewerage which contains considerable amounts of textile wastes.

As a corollary to these two specific research jobs, there will be established a clearing house for the collection and distribution of information on work other than that directly authorized by the Foundation. It is expected that this clearing house will in time be able to furnish information to textile manufacturers, engineers and others dealing with textile waste problems, but of course the clearing house will not assume the capacity of a professional consultant.

"*NATURAL silk, wool and animal hairs in general, belong to that class of biological compounds known as the proteins, Nature's grandest work in the architecture of molecules. The protein molecules seem to be almost terrifying in their complexity; they are the physical and chemical basis of life itself. But we must not let them frighten us unduly. There was a time when the problem of the structure of asbestos appeared nearly as hopeless—yet now it is solved. Great advances, too, have been made in the study of cellulose. Need we doubt then that the protein molecules also will sooner or later yield their deepest secrets to careful experimenters and patient thinkers?*"—W. T. Astbury in "Fundamentals of Fibre Structure."

Research on Textile Drying

Conference Demonstrates its Need and Asks U. S. Institute to Undertake It

BY a practically unanimous vote the 150 manufacturers and representatives of drying machinery, control instrument and other firms who attended the conference on textile drying problems, held under the auspices of the Research Council of U. S. Institute at the Hotel Pennsylvania, New York City, May 6, went on record in favor of having the Institute undertake the organization and financing of a research on the drying of textile materials. At a meeting of the Research Council following adjournment of the conference Chairman Emley, vice-chairman Smith and Alban Eavenson were appointed a committee to draw up a prospectus of the subject or subjects for the research and tentative plans for the study and its financing. Their report, together with a complete stenographic report of the conference, has been mailed to those who registered for receipt of the latter, and another meeting of the Research Council and the Executive Committee of U. S. Institute will be held in New York City, Wednesday, June 3, to complete plans for the study.

The Morning Session

W. E. Emley, chairman of the Research Council, presided at both the morning and afternoon sessions of the conference, introducing the former with an outline of its purposes and the subjects to be covered, and closing the latter with a summary of the discussion. Dr. E. H. Killheffer, first vice-president and chairman of the Executive Committee, welcomed members and guests to full participation in the discussion, noting that the large attendance justified the previous conclusion of the Research Council that there had been insufficient study of this important subject, and that it is high time that it should be approached scientifically and some of the "hickies" dug out.

The morning session was given over to the reading of papers covering the drying of the principal types of textile materials, and the machinery and principles of drying. The papers and their authors were as follows: Cotton Drying, Samuel B. Bird (read by P. B. Wendler); Wool Drying, E. N. Angus; Rayon Drying, Dr. F. Bonnet; Drying of Silk Hosiery, Erb N. Ditton; Textile Drying Apparatus, James T. Hunter; The Mechanism of Drying Textile Fibres and Fabrics, Lucien Buck; Importance of Air Movement in Drying, B. M. Jones.

Before reading his paper Mr. Wendler stated that it was to have been presented by Mr. S. B. Bird, but that the latter was unable to be present owing to the serious illness of his uncle, Mr. Joseph Bancroft.

In introducing Mr. Ditton, Chairman Emley stated that Mr. Ditton had told him that he was not qualified to speak on the broad subject of silk

drying and could speak only for silk hosiery, "But," said Chairman Emley, "frankly, I don't believe him."

The Afternoon Session

The afternoon session convened immediately following luncheon at 1:30 P.M., and the discussion, which was unusually frank and instructive, continued until 4 P.M., when the conference adjourned. Prior to adjournment and in answer to questions from those present Dr. Killheffer, Dr. Smith, Mr. Eavenson and Secretary Clark explained how previous researches had been organized and financed, and the methods that might be utilized for a study of textile drying. Following their remarks Chairman Emley asked those who favored having the Institute undertake the organizing and financing of a research on textile drying to raise their hands. As previously stated the response was practically unanimous, only two hands being raised when he asked for those who did not think such a study worthwhile.

Chairman Emley's introductory remarks at the morning session and his summary of the afternoon discussion, Mr. Eavenson's introductory remarks at the afternoon session, and the papers read at the morning session are published in this issue. Unfortunately, lack of space and delay in the editing of the stenographic report of the afternoon discussion prevent its publication in this number. An outline report of it will be published in the July number, but those who wish the complete stenographic report may obtain it by forwarding $1.00 to the Secretary. This was the basis upon which those who registered at the conference obtained it. A bibliography of textile drying, which had been compiled by Secretary Clark, was distributed at the conference and will be published eventually. Subscribers desiring a copy prior to publication may obtain it free of cost, as long as the mimeographed supply lasts, by addressing the Secretary.

Chairman Emley's Introductory Remarks

IN order to place before the meeting conclusively the topic that we are about to discuss today, I am going to take the liberty of retelling to you things which you already know but may have forgotten, since you probably do not think of them every day. In our school days we were taught that water boils at 212°; that to dry any material it is merely necessary to hold it at 212° for a sufficient length of time, and that when the temperature went up to 213° our material was dry.

But the present generation has added much to the complexities of life, and we know that all of those statements can be accepted only with major qualifications. Water does not always boil at 212°. In fact, the word "boil" has lost its definitive meaning. We now have to resort to a rather complicated statement by saying that the rate of loss of water from a material is a function of the difference between the vapor pressure of the water in the material and the partial pressure of the water vapor in the surrounding atmosphere. What it means is that the water in the material is always trying to get out and the water in the air is always trying to get in, and whether the water goes this way or that way depends upon which side the vapor pressure of the water is the greater, and the rate, of course, depends upon the difference in the vapor pressure.

From that it follows that circulation is an important factor, because if

the water starts to come out into the air and the air is not moving, of course the air will continuously build up more and more water until the vapor pressure of water in the air becomes the same as the vapor pressure of water in the material and then we have an equilibrium condition and no vapor is given off. But if the air is circulating so that fresh dry air is brought into the material all the time, the loss of water from the material can be continued.

It follows from that concept that a material can be dried very much below 212°. All that is necessary is a continued circulation of air around the material, the air having a lower vapor pressure of water in it than the vapor pressure of water in the material. In fact, the material could be dried at temperatures below zero if you were patient enough to wait long enough for it. Also we know from experience in steam practice that water may boil much above 212°. In high-pressure steam boilers the water boils perhaps at 350°.

The vapor pressure of water in the material depends in general upon three factors: (1) the amount of water in the material, (2) the temperature of the system, and (3) what we may call the adhesion of the water to the material, which is a specific property of each material.

On the other side of the picture the vapor pressure of water in the air will also depend upon three properties: the amount of water in the air, and its temperature, and then, as I mentioned before, the circulation. So that we have to balance these.

What I have said applies to any material, not specifically to textiles. With textiles the situation is still further complicated both chemically and physically. Chemically, do we know that when we dry a textile material the loss of weight is all water? We have very definite evidence, for instance, that when we dry vulcanized rubber some of the loss of weight is hydrogen sulfide. We have not quite so definite, yet pretty conclusive, evidence that when we dry a sample of leather some of the loss of weight is carbon dioxide. How about when we dry a sample of wool; is the loss of weight all water, or is there some danger that certain drying conditions may cause permanent chemical changes in the fibre structure?

Physically, we are all familiar with the phenomenon of hysteresis. When a fabric is brought to equilibrium with a given atmosphere, it will contain more water when the equilibrium is approached from the wet side than it will when the equilibrium is approached from the dry side. If a textile material is dried too rapidly or too completely, is its ability to absorb water permanently impaired? That is to say, if you bone-dry a sample of material will you ever be able to get back the normal amount of water into that fibre? And of course we all know the property in the fibre is very vitally dependent upon the amount of water that it contains.

Presumably it should be possible to establish a set of optimum conditions for the drying of any given kind of textiles, such that there would be a maximum output per unit of fuel consumed and per unit of floor space, per unit of capital investment, together with a minimum of damage to the fabric.

The purpose of the meeting today is to discuss questions like those enumerated, in the hope of arriving at a general agreement upon answers to the following:

What, if any, are the drying problems of the textile industry?

Is any problem in this field of sufficient practical importance to justify financial support from the industry for its solution?

Before throwing these questions open to general discussion, we thought it would be advisable to place the picture more definitely in your minds by having a short set program. In this program we are to have the drying problems discussed from the standpoint of the four textile fibres—cotton, wool, rayon and silk—and then followed by some papers describing the problems from the other side of the picture, that of the machinery manufacturers. I shall ask you to make notes during the presentation of these papers in order that when the opportunity comes this afternoon you may have your questions all ready. There will be no discussion during the presentation of papers. That will be held over until this afternoon.

Alban Eavenson Defines Purpose of Meeting

Mr. Chairman. Gentlemen, your chairman thinks I am good at starting controversies. At any rate I will do my best. This meeting was called not with the idea that there should be any question as to whether textile drying represented a subject for research; it was a little more specific than that: It was to determine whether there were sufficient general laws and truths underlying every branch of textile drying which would make it a worthwhile research subject, or whether the differences in the fibres themselves were such that it would be necessary to split up the problem into a number of smaller problems involving each particular fibre, and perhaps going even further and involving different types of dryers, and fabrics and yarns as well as raw stock. We assumed that there was a problem, and your presence here indicates that our assumption was right. This meeting is to help us to determine just how it may be handled best.

After the meeting the Research Council will have to go into a huddle and determine: (1) was it the consensus of the meeting that this is a single problem? (2) is there a sufficient groundwork here for one general problem? or (3) should we split it up into its several branches, in which case it would seem more proper that each of the fibres should be handled individually. We would then have to give you some idea of how we propose to go about it and what it is going to cost. Now we can only get at that if we can provide an atmosphere here in which you all will feel free to get up and talk. Dr. Killheffer just suggested that I get up and say, "I don't believe a damn word of anything that has been said here," and start a real red-hot swapping of opinions. I want you to feel free to do just that for this reason: that if anyone has any remarks to make which he would not wish to have broadcast and will so state, that wish will be respected.

If I may start a little controversy, I think this morning there was too much stress laid on the subject of economy. I have read the advertisements of drying machines—economy in steam per 100 lbs., economy of floor space, production, etc. Personally, I think all this is unduly stressed. I know in our own field of work, which is wool, we are far more interested in quality that we are in the question of economy. We aim at all times to have our stock leave a dryer as near as possible to the condition in which it went into that dryer, with none of its qualities altered; in fact, just the same as it went in minus its moisture. That is what we aim to get.

The work of Dr. Harris at the National Bureau of Standards has shown that wool is a very peculiar substance. I think we are all prone to look upon it as a sort of inert material, not liable to change. But his work has brought out that there is a critical condition of moisture and temperature at which degradation starts very rapidly. He has pointed out that it is a

very, very easy matter to disturb the sulphur and nitrogen ratio, and once disturbed they can never be restored. He has brought out a lot of very fundamental things. One of them in particular, which I think did me more good than anything else I have learned through that study, is that wool can be so treated, particularly in oxidation processes, that while there may be no apparent change (no change which we can measure in strength, elasticity, light reflection, compressibility, any of the ordinary physical tests) at the same time that fibre has been so changed that it is what I may call very susceptible to damage, susceptible to subsequent treatments in dyeing, or fulling, etc.

I preached for years—I was a kind of outside man going around getting business, you know—that if we preserved the elasticity, the color, the strength of the fibre, that anything which happened to it subsequently must of necessity be the fault of those subsequent operations. I have got to confess that that dope was all wrong. And I know that in some of the remarks this morning it was quite evident that there was a lack of appreciation of some of those fundamental things, and the object of this meeting today is to bring out an atmosphere where you can freely discuss them.

Our Mr. Angus, who happily is with us, has had a lot of experience in drying a great many materials other than textiles, and I think one of the things which was most helpful to us was the experience which he had in drying certain types of lumber for use in making the blocks which the printer uses, whatever you call them. At any rate, those blocks must be kept for years and years and their shape must be absolutely true. They must not warp in the least, because if they do they are valueless; they will not take the imprint. That can only be done by slow, conditioned drying. Quick drying case-hardened that wood so that the outside was very, very dry and the inside was quite moist, and they were bound to get out of shape and be quite valueless. I rather thought that that principle applied to wool drying. We have since proved that it does. If it applies to wool drying, certainly wood is much more similar to rayon or cotton than it is to wool, and it would seem almost certain that it would apply more so to those vegetable fibres than to wool. But I didn't come here to talk about that. Now you fellows go to it.

Summary of Discussion by Chairman Emley

When we started out this afternoon it seemed to be a rather generally held opinion that high temperatures in drying were advantageous in increasing the output of the equipment, but that high temperatures in drying might be dangerous in that they might do some damage to the fibre. So there were two points of view which should meet somewhere to give the optimum conditions: maximum output with minimum danger of damage. But when it came to a question of deciding what is a high temperature and what is a low temperature, the statements didn't seem to be so very definite. I am referring now particularly to the temperature of the goods themselves and not the temperature of surrounding air, which of course is an entirely different question. It would seem as though some fundamental information were needed to find the maximum temperatures which can be used with the minimum damage. Then also there has been injected into the picture other variables which must necessarily be considered: the question of the duration of the drying and the question of the atmospheric pressure in the dryer.

Cotton Drying

By SAMUEL B. BIRD *

THE subject of drying of cotton is one that apparently has been taken as more or less a matter of course in most of the literature on finishing as very little mention of it from a chemical standpoint, as far as I can discover, is made as affecting various processes. We ourselves have not pursued active research along these lines, but rather along the lines of increased production.

Drying seems to fall into three natural divisions when applied to fabrics, under industrial conditions. They consist of (1) contact drying without pressure, i.e., can drying; (2) hot air drying, i.e., tenter drying; and (3) the drying as done under heat and pressure, i.e., calendering.

The results of can drying usually have a harsh feel and are fairly stiff. In most cases they are almost bone dry. This necessitates the addition of softening agents during finishing which might be materially reduced if the fabric were allowed to dry naturally in the air. A rather good illustration of this is given in the home laundry. During bad weather when clothes are hung up to dry in a heated room, they are much stiffer and harsher in feel than when dried out-doors on a line, and necessitate more dampening before ironing. Also, where chemical processes are utilized it has been illustrated that dehydration between various steps produces different results than when the fabric is left wet. There must be, therefore, some definite change in the fibre on dehydration, and it must be permanent to an extent, as on wetting out the effects seem to be different when dried a second time. Also, wetting out between chemical processes will not give the same result as it would had the fabric not been dehydrated. What this change is we don't know, but it might be interesting to discover, if possible, through research, what changes do take place, thus giving us a better understanding of what produces variations for which we cannot now account.

Tenter drying, as a rule, doesn't present the same results that can drying does. Here, however, higher and higher temperatures with more rapid circulation have been the rule in recent years, in order to increase production by increasing the rate of moisture evaporation. The heat in some cases has reached the point where some of the constituents of the softening agents are volatilized, thus making it necessary to use a greater amount of softener for the desired finish. It also results in heating the cloth to such an extent that damping before calendering is doubly necessary.

In former years plenty of time was allowed for conditioning, but today, due to the market conditions, fabrics that come out of the bleach today must be shipped two days later, or sooner; this allows for a very short conditioning time, which, due to the high temperatures used, should really be increased. I believe for the finisher this is perhaps the greatest problem in connection with drying. The approach to air drying would, therefore, be of great help to him.

If a fabric is damped to too great an extent before calendering the result is apt to be thin, and have a crisp papery feel. This may be removed by swelling the fibres again through wetting out the fabric, drying, damping, and re-calendering. However, the fabric never seems to return to the same condition that it would have if it had been properly handled in the

* Joseph Bancroft & Sons Co., Wilmington, Del.

first place. Some of this is due undoubtedly to the short conditioning time, and to the high temperatures used in drying that necessitate the excessive damping.

The normal moisture content will be regained, as may easily be illustrated by weighing experiments, but the fibres seem to have undergone a permanent change. However, where excessive heat is used, it is well known that the strength of the fibre is reduced, and it is not regained when the moisture returns to normal. This is confirmed in an article by B. Tenfer which appeared in 1927, in which he notes the same phenomenon. (Zeitschrift für gesellschaft Textile Industrie: "Is drying being done properly," 1927, 3–29.)

In connection with dyeing, it is well known that at the high temperatures used in the modern tenter, the shade is apt to change; for example, blues will go red. We wonder, therefore, if we may not be pursuing an erroneous course in our efforts to increase production by going to higher temperatures. Could some other methods of drying be designed using lower temperatures, greater volume of the drying medium, more rapid circulation, and so on, which would give us a better conditioned fabric with which to work? We believe it is worthwhile investigating.

Wool Drying

By E. N. ANGUS *

THE drying rate of any hygroscopic material is in exact proportion to the vapor pressure of the air surrounding that material. Regardless of the commodity, the three fundamentals of drying always must be applied: that is, the temperature, humidity and circulation of air, each in its relationship to the other, govern and control all drying. The quality and quantity of results obtained are exactly equal to the quality and quantity of knowledge the operator has of the product being handled.

The ideal drying problem would be presented by a product that would allow the unrestricted transfusion of either its free or imbibed water without any change to itself physically or chemically. Unfortunately, there is no such ideal to be found among the vegetable or animal products.

Any cycle or schedule of drying of a product must be based definitely upon that products' proportion to the ideal. It is unreasonable to expect efficiency in any type of drying without complete knowledge of the products' ability to withstand, without injury, an accelerated setting of drying conditions.

Theoretically, but not without its argument, natural drying is the perfect consummation. We hear, from time to time, those days of wonderful scoured wool drying with only a cloudless sky and a hot sun's rays as a drying machine. It is with wonder that we accept such statements, since a perfect duplication, mechanically, of every set of air conditions nature has to offer will produce a very inferior drying result as compared to accelerated unnatural drying. In the first place, a uniform schedule must be used, such schedule to apply only to a uniform product. There are no two grades of wool that can be dried with the same schedule of drying. The setting of drying conditions may vary but little from lot to lot, but that seemingly minute difference may cause a far greater damage than

* Eavenson & Levering Co., Camden, N. J.

one can realize, especially if drying is being done upon what is known as borderline methods. Borderline drying is that accomplished in a machine which, after being designed for 500 lbs. an hour, is constantly delivering 600 lbs.

The drying of secured wool has, generally speaking, received altogether too little real research. It is impossible not to believe that case hardening occurs in wool drying; that surface stress, far from normal, does not present itself; or that fracture, bordering on explosion, does not occur. Does any degree of heat above that to which the unshorn wool is subjected cause any rearranging of the unknown elements chemically? Is there a general shrinking of fibres with their permanent harshness? Not having the answers, in other words always hoping to find them, offers an attractive field, the surface of which has but a few minor scratches on it.

What has been done and what is being put into practice today with the present knowledge is far from perfect to be sure, but likewise is every other process. Scoured wool drying today is being handled speedily with a very uniform known condition, but not without continued vigilance on the part of the operator. Careful watching with help of the highest grade of accurate control instruments, controlling always less vigorous schedules than the wool is known to be able to withstand, has put the quality almost on a par with the drying of others of nature's products that are more uniform. Just how far toward perfection we may eventually go depends, almost in its entirety, upon the research chemists and their ability to offer the engineer those facts that can be applied to the product commercially.

As mentioned at the start, drying is a problem of differential vapor pressure. Such being the case we may well term drying as a very definite branch of air conditioning. It so happens that humidity controlled drying actually came before what we now call air conditioning. To be sure the control of the humidity (or call it vapor pressure if you wish) was crude those first few years, and for that reason it could not reach the public building field where it could really be realized. Today, however, we use in drying these very same advanced instruments that a much larger field has given us. Uniform drying cannot take place, nor can satisfactory drying be accomplished, without a control of the moisture in the air surrounding the wool. Normal room air taken into a drying machine, and heated with no regard to moisture content after heating, is the one greatest point toward wool damage. One will say that the proportion of this new air is slight and the moisture from the drying stock takes care of this point. True this is, and very true indeed; in fact it is so true that if such were not the case it would be impossible to do even a bad job of drying. If this natural humidity control is the salvation just how far do you feel an improved result could go if the control was exactly correct for the type of wool and its own condition?

Getting down to actual facts is usually interesting. It is generally understood that our regain charts are accurate. They are based, as you all know, upon the definite relationship between air moisture and wool condition. This relationship is very important in the drying cycle. If stock enters the dryer with 40% condition, it cannot be subjected to an air condition that would show a regain of 13% without serious results. Neither can the same stock be subjected to an air condition that would show 2% regain and be expected to leave the dryer at 13%. The air condition cannot at any time during the drying schedule be lower than that which would

produce the desired final condition in the wool. Such a procedure carefully controlled is the only method on earth that will produce absolutely uniform dried wool of any wanted condition. Under such operation wool could remain in a dryer for an indefinite period and its final condition would be exactly the same as at the time equilibrium was originally reached.

Much has been discussed regarding the initial or first temperature the cold wet stock comes in contact with. First of all, there can be no drying until the temperature of the wool and water is raised to a point of evaporation. When evaporation starts it must be slow and carried on with a very humid air; slow to prevent surface drying and wilting, and with humid air for much greater and faster penetration. In many operations a completely saturated air is used for the warming up period, and its higher specific heat speeds up the process to such an extent that the small amount of moisture picked up by the wool is of no consequence. A thorough initial warming will be found to result in a better balanced stock, provided of course the drying schedule after warming is within reason. Sudden shocks caused by too rapid changes from one section of a dryer to the next are certain to cause damage nearly equal to that caused by excessive temperatures.

Going a little further along into the realm of controlled drying, we find that the wet-bulb reading is the same as the temperature of the wet stock, as evaporation is taking place at like rates, both at the wet-bulb wick and from the stock. This same equality exists throughout the entire procedure if the machine is designed to exacting standards. As the wool is never brought below the point where no evaporation exists, the lowered temperature of evaporation prevents much of the bad effect of high dry-bulb temperatures. Then, under accurate humidity control it is possible to use drying temperatures far above that which would ruin stock with other methods. Higher temperatures mean greater evaporation, which greatly offsets the slowing down naturally offered with controlled drying. Some vegetable products are being dried today at temperatures which, if not humidity controlled, would burn them to a crisp.

Drying in the shortest practical time without sacrificing quality is the aim of every operator. Generally speaking, the shortest time that is conducive to satisfactory results is the best method, as any process that is prolonged enacts its toll in some form or another. In order that the time element may be kept within the limits demanded for control of heat, humidity and circulation it is of utmost importance that all stock entering any drying machine should be of uniform condition. It is an impossibility to design drying equipment that will correct variation in condition without a great loss of time. It would appear that uneven washer output, poor squeeze rolls or incorrect pressures on rolls are the greatest contributors to the cause of such variation.

As the wet stock is fed from the feeding device to the moving apron or screen there must be every precaution taken to control the uniformity of the stock flow. While the percentage of the wool may be constant, as far as moisture content is concerned, there is an everchanging drying problem if the layer of stock is of a thick and thin nature. In all cases of bulk drying the feeding is most certainly an important contributor to the success of the final result. Correcting an uneven feed with all of its attendant evils is purely a mechanical problem.

All in all there remains a lifework of the most interesting research in drying alone. Back of the scenes of drying there are problems unlimited.

Regardless of mechanical perfection, coupled with complete knowledge of the product, there can never be one drying machine that will actually improve wool. The perfect wool dryer, if it is ever designed, will still be a machine delivering from its doffer end the exact quality of wool that enters the feed end, minus its unwanted moisture.

Rayon Drying

By Dr. F. BONNET *

RAYON is a hygroscopic product which will take on or give up moisture, depending upon the relative humidity (R.H.) of the air to which it is exposed until it reaches a state of equilibrium with it. Such an equilibrium for any given condition of air humidity depends upon whether the yarn approaches it from the wet or dry side; that is to say, whether it is a case of desorption or adsorption. Urquhart & Echersall in the *Journal of Textile Institute* Transactions, Aug. 1932, published some very valuable results on such equilibria for various rayons, including acetates. Thus, they find that at 25° C. (68° F.) with a R.H. of 10%, regenerated cellulose yarns (viscose, copper-ammonia, nitro-process yarns) show only about a 4% moisture, while at 55% R.H., about 11%. The acetates, on the other hand, under the same conditions show about 1% and 5% respectively. Rayons are therefore sold under a standard moisture content 9.9% (or 11% regain) for the regenerated cellulose type, and 6.1% (or 6.5% regain) for the acetate type. Rayons with this latter moisture content are, of course, perfectly dry in the ordinary sense of the word. A R.H. of 55–60% at ordinary mill temperatures is also most generally accepted as the best condition for processing rayons into fabrics, especially those of the regenerated type, and it is primarily this type which we shall consider in this limited introduction.

In processing rayon into fabric it is necessary in most cases to wet out the yarn and dry it not only once, but often several times. Thus, if the yarn is skein-dyed, or treated with an aqueous solution for crêping purposes, it is dried in the skein form, and after weaving it is wet out again in the scouring and dyeing operation and then dried again as fabric. All these dryings may be accomplished without altering materially the properties of the natural yarn, but improper drying will produce serious alterations in the yarn causing such poor dyeing and finishing that considerable loss may result.

In drying rayon it must be remembered that we are dealing with a carbohydrate. If heated in a dry atmosphere for some time the yarn gradually turns yellow and serious changes in the physical properties take place. The dye absorption, for example, the tenacity, extensibility and ability to crêpe are all lessened, the degree depending of course upon the temperature and the time of exposure to the excessively dry condition. The yellowing of the yarn is really incipient charring, analagous perhaps for ready comparison to the carmelizing of sugar.

It is a common thought that in order to dry anything containing moisture it is necessary to heat the material to or slightly above the boiling point of water whereby the moisture is driven off as steam and the sub-

* The Viscose Co., Marcus Hook, Pa.

stance left dry. This is, of course, true only if under the drying condition the substance itself is not changed, and cellulose dried at temperatures quite below the boiling point of water is affected and changes take place in dry heating suggestive of incipient charring; but it is not necessary nor desirable to dry it bone dry, for the "natural" yarn, as has been pointed out, is normally dry with approximately 10% moisture in it.

The simplest, and certainly the safest way, is to air-dry the yarn or fabric at ordinary room temperature, but this takes quite a long time and is therefore impractical for any large scale operation and production. Higher temperatures will, of course, shorten the time required for drying, but they also increase the danger of overdrying and of materially changing the properties of the yarn. For safe ordinary drying it has been recommended that temperatures should not exceed 130° F., and the natural rayon dried at this temperature for about four hours shows no appreciable decomposition. However, in the commercial operation of dryers, both skein and festoon, fairly high temperatures of around 180° are commonly used and for the most part we must admit with fairly successful results; but this, in our opinion, is due more often to the usual limited capacity of the dryers for the goods to be dried and the rather short routine time the yarn is in the dryers, than to really intelligent or safe operation. In other words, the yarn for the most part hasn't been given an opportunity to reach this temperature but only that of the wet-bulb temperature. Such drying leaves too much to chance and is therefore unsound, and, at best, certainly unsafe. In this connection we have in mind a case where skein yarn was being dried at about 180°, and, due to some interruption in the routine, a lot was left in the dryer with the steam full on for a much longer time than usual. As a result, this lot dyed a lighter shade, particularly the outside of the skeins where the drying was most severe, and was not the same as previous or subsequent lots. It was obvious the yarn had been over-dried and its properties changed.

We quite fully appreciate the desirability from a production point of view to raise the temperature as high as possible so as to get rapid drying and increased production from given equipment, but with merely a dry-bulb temperature control such drying is unsafe and therefore not to be recommended. It must also be remembered that in the commercial processing of rayon into fabric it is rare that merely the yarn itself is dried. In preparing yarn for crêping it is treated with so-called throwing compounds consisting of adhesives (e.g., gelatine, gums or a combination of these), softening agents (e.g., sulphonated oils) and tints. After extracting, the damp skeins are dryed so that not only does the drying involve the rayon itself but is complicated by the effect of the drying of these adhering substances and their effect on the rayon. This particular problem is under investigation by the Throwster's Research Institute. A similar problem concerning warp sizing is being investigated by the U. S. Institute for Textile Research.

Considerable attention has been paid to controlling the dry-bulb temperatures of dryers, but comparatively little to that of the wet bulb. We have pointed out that rayon is a hygroscopic compound and that its moisture content depends upon the R.H. of the atmosphere to which it is exposed. While the work of Urquhart & Eckersall give definite figures for a dry-bulb temperature of 25° C. (68° F.), no actual figures are available as yet for temperatures around the boiling point of water. Nevertheless, it

is logical to assume that a similar relationship exists between Relative Humidity and moisture content of the yarn at elevated temperatures. Assuming for the moment that the moisture content of yarn is approximately the same at high as it is at ordinary temperatures, then for a drying temperature of 180° F., for example, it would be necessary to maintain a wet-bulb temperature of 134° F. to have a 30% Relative Humidity in the dryer, and the yarn could not be dried below a 5–6% moisture content which would protect it from any appreciable change in composition or properties. It would seem well worth while to establish the actual figures for such drying.

We now turn to the drying of sized warp yarn on a slasher, for one of the rather common causes of warp streakiness is overdrying some ends of the warp on the steam-drum dryer. Sometimes the sizing material itself seems to be quite as much or even more affected than the yarn, giving rise to decomposition products which are practically impossible to remove from the yarn by the ordinary scouring, and these act as dye-resists on the yarn if they have not also affected the yarn. The slightly tighter ends in a warp will tend to come in more intimate contact with the hot steam drum, become dried out first and then over-dried with a change in composition and dye absorption. This condition has apparently been recognized and has led to the development of air-drying slashers in which it is possible to control the air humidity for safe uniform drying of the yarn and size.

In finishing, the "hand" and quality of a fabric can be quite ruined by dead drying either in a festoon or net dryer, on the tenter (especially an open tenter), or by the temperature to which the fabric is exposed on a hot calender. If once a rayon fabric has been over-dried no subsequent treatment with emulsions, soaps or finishing oils will give it the "hand" and quality it would otherwise have had.

The proper operation of a Palmer, to which the cloth should go in a somewhat damp condition, is a practical recognition of not over-drying. The steam of the damp woolen blanket prevents dead drying even though the temperature may be relatively high. The effectiveness of decatizing, i.e., steaming the fabric in a blanket roll, is a further illustration, but the importance of not dead drying the fabric before decatizing has not been so well recognized and no doubt accounts for some of the apparently contradictory results sometimes obtained. Decatizing will not restore the quality and properties to a fabric which has at some stage been over-dried.

Summary

(1) It is a recognized fact that rayon should not be dried in a dry atmosphere above about 130°.

(2) Drying at elevated temperatures in a dry atmosphere is unsafe, both as to the rayon itself and the compounds on the yarn (size, dyes, throwing compound).

(3) Drying at elevated temperatures is being done with apparent success but not in a dry atmosphere.

(4) Data obtained at lower temperatures show that the yarn reaches a state of equilibrium of moisture content depending upon the Relative Humidity of the atmosphere to which it is exposed.

(5) It seems logical to assume that approximately the same relationship holds true at elevated temperatures, and that drying at elevated

temperatures can be safely done if the Relative Humidity is controlled by maintaining a wet-bulb temperature which will not permit the moisture content of the yarn to go below a definite minimum, say 5–6%.

(6) Accurate data for the most economical control of drying at elevated temperatures are not as yet available and would seem to be a problem for this Institute.

Drying of Silk Hosiery

By ERB N. DITTON *

THE primary purpose in any drying operation is obviously the removal of excess moisture, and this is of course true in the case of silk hosiery. However, since the physical properties of the silk are not affected by the relatively low temperatures used and the short time of contact, the emphasis must be shifted to other factors than the mere drying. In this special case, therefore, the emphasis is placed on other objects and the drying itself becomes for all practical purposes secondary to these other objectives, which may be summarized as follows:

(*a*) To make the stocking conform to its proper shape. In the case of full-fashioned stockings, they have been knit into this shape, while in the case of seamless (circular) knit the drying operation is somewhat of a shaping one as well.

(*b*) The pulling of the stocking to its normal length.

(*c*) The putting of the hosiery in such a flat shape that the subsequent inspection, folding, and boxing may be satisfactorily carried out.

(*d*) The drying in such a manner that whatever finish or size has been added, during or subsequent to the dyeing operation, may be set so as to give the finished product the desired appearance.

The importance of these four factors is in reality greater than the mere removal of excess moisture, so that the satisfactory operation of any drying equipment must be considered, for all practical purposes, purely from this standpoint.

General Procedure

After the hosiery has been removed from the dye bath, they are placed in a hydro-extractor (centrifugal) and the largest portion of the excess water removed. The amount of moisture left in the goods before the final drying is of great importance for the final appearance after drying.

There are two factors to be considered in determining the correct moisture content to be left in the goods after extraction:

(*a*) In general, the wetter the goods when they are placed on the final drying equipment, the better will be the general appearance, as there is less chance of a part of the fabric drying out before it is properly placed on the drying forms. In addition, sufficient moisture at this point allows parts of a stocking such as the welt (hem) to be properly straightened out before it has a chance to become too dry.

(*b*) If, however, the fabric is put on the drying form when too wet, the work will be too hot for the hands of the operator to touch, and burns and blisters will result.

* Gotham Silk Hosiery Co., New York, N. Y.

(*c*) The exact amount of moisture left after extraction must be determined by experimentation for each type and weight of fabric, working between the limits mentioned.

It is advisable to equip the extractor with an automatic timer and brake, so that once the proper time of extraction has been determined it will be possible to maintain this time for all subsequent lots.

Since, in normal mill operation, quite a period of time will elapse between extraction and final drying, it is important that merchandise be covered with a damp cloth or wrapped in wax paper to prevent the loss of moisture.

Types of Drying Equipment

There are three general types of drying equipment in general use at the present time:

(*a*) Wooden drying forms with an external application of heat.

(*b*) Metal drying forms with an internal application of heat.

(*c*) Metal forms with the heat applied externally.

Wooden Drying Forms

This type of equipment is the oldest in use in the hosiery industry, and while possessing many advantages is not used to any extent today. The operation of such equipment may be briefly described as follows: The hosiery is placed on wooden forms shaped so as to fit the stockings to be dried after extraction, and the forms are then placed in racks in a drying oven supplied with steam coils and a fan and left until the drying is completed. The temperature within the drying box is generally about 180° F. and the time for drying is from eight to ten minutes. The forms themselves are made as thin as possible without sacrificing rigidity and have beveled edges so that the goods will lie as flat as possible after drying.

This type of equipment gives the best "finish" of all kinds in use, at least as far as sheer hosiery is concerned, as, due to the poor heat conductivity of the wooden forms and the external application of heat, the forms themselves are practically cold when the wet goods are put on. This prevents the drying out of a part of the work before the entire stocking has been placed on the form. By turning the form while the work is being applied, the operator can see both sides of the form and thus "set" the work properly on both sides. Defects on both sides of the drying form can be detected. Temperature adjustment is easy.

Among its disadvantages are high cost, due to the slowness of the operation; large space requirements; great physical effort on the part of the operator made necessary by the carrying of the forms to and from the drying oven.

Internally-Heated Metal Forms

Such equipment consists of hollow-aluminum or stainless-steel forms, internally heated by steam. This type, in one of its several forms, is the most widely used today in the hosiery industry. The temperature on this equipment varies from 230° to 212° F., dependent upon the heating element used, and the time varies from two to five minutes.

Advantages.—(*a*) The labor cost is from 10 to 15% lower than on wooden forms. (*b*) Space requirements are the least of all types. (*c*) Low maintenance costs.

Disadvantages.—(*a*) The finish is not as good as on the wooden forms, as, due to the fact that the forms are very hot at all times, part of the fabric dries out before the entire stocking has been properly put on the forms. (*b*) Since only one side of the form faces the operator it is difficult to adjust the work properly on the back of the form. (*c*) Defects can be seen only by the operator when on one side of the form. (*d*) Due to the necessity of space for steam inside the form, such equipment cannot be made as flat as in the case of wooden forms. (*e*) The stockings having been knit to a definite foot size, it is necessary to have drying forms for each particular size, of which there are six in general use. Since in normal plant operation the merchandise frequently does not come through in the average size assortment, this means that either more equipment must be purchased than would otherwise be necessary, or that at certain times some of the work will be held up as an insufficient number of drying forms will be available to handle certain sizes.

In attempting to overcome these disadvantages several modifications have been made in recent years: (1) The insulation of the form at various points. (2) The use of hot water for heating instead of steam. This method of heating, while satisfactory for sheer goods, is unsatisfactory for heavier goods and particularly for merchandise with cotton tops and feet. (3) The mounting of the forms on swivels so that both sides can be seen.

In addition, electrically heated metal forms have been developed and found of some use, but, due to the high cost for the large amount of current consumed, have never found wide adoption. These forms have certain advantages such as easy regulation and change of temperature and thinness, but their high cost precludes their use except in the case of the most expensive merchandise.

Externally-Heated Forms

In this case, thin aluminum or stainless-steel forms are used which are generally mounted on an endless chain which moves them in and out of the drying oven, the latter being supplied with steam coils and a fan. This type of equipment, while not new, is the latest development in the industry and its use would appear to be increasing. The temperatures used vary from 160° to 190° F. and the time of drying is about three minutes.

Advantages.—(*a*) Lowest labor cost; about 45% of the cost of the wooden forms. The saving is due to the fact that the forms are mechanically moved into and out of the drying oven, and that it is only necessary for the operator to put the stockings on the form as they are stripped mechanically. (*b*) The finish is intermediate between wooden and internally-heated metal forms, as the forms, while cooler than in the latter case, are hotter than in the former. (*c*) Easy temperature adjustment. (*d*) This is the only type of equipment which, due to its construction, can be made so that the foot size can be changed at will. This allows the maximum production to be obtained from the minimum amount of equipment.

Disadvantages.—(*a*) Maintenance costs are higher than in the other types, but the increase is insignificant when compared to the decreased labor costs. (*b*) Larger space requirements than in the case of internally-heated metal forms, but less than when wooden forms are used.

In recent attempts to improve the "finish" of this type equipment, spraying equipment has been developed which wets the goods after they are

put on the form and before they enter the drying oven, thus assuring uniform drying as in the case of wooden forms. The spraying may be either done with water or steam, but this development is too recent to make any definite statement as to its advantages except that it would appear to be promising.

Conclusions

In conclusion, many experiments have shown that neither the temperature nor time of contact in any of the methods described is harmful to silk hosiery fabric. For example, stockings have been left on drying forms at 230° F. for three hours without any deterioration in any of the physical characteristics of the silk.

The type of equipment to be used in any given case would depend largely on the quality of finish desired and the labor costs involved in any given locality.

It would appear that more attention should be given to the moisture content of the goods before they are placed on the drying forms.

Textile Drying Apparatus

By JAMES T. HUNTER *

Principles of Design and Operation

ALLIED to the important question being investigated, to wit, temperatures and their effects upon fibres, possibly of equal interest to you will be a brief consideration of the problem of drying, both from the point of view of the builder of the apparatus and from that of the manufacturer of textiles.

Drying is one of the most important but, sad to relate, neglected operations of textile manufacture. The old adage "Every man to his trade" applies to the builders of dryers, as it is rather beyond their scope to attempt any specialization in the effects of drying all the various stocks and fabrics to be handled. Drying tests on various samples, both raw stock and fabrics, can be made to determine required air velocities, temperature ranges, steam consumption and rate of production. Further study of fibre reaction, such as tendering, weakening, harshness, etc., is a problem for the chemical laboratory.

Certain engineering data are used in connection with the design of drying apparatus. There is neither the time nor, perhaps, the necessity of being super-technical in covering that subject, and certainly you do not wish to have an excess of theoretical dissertation about drying phenomena. That portion of the subject is, by itself, sufficiently dry to omit.

However, entering into the building of textile drying apparatus is a study and knowledge of physical laws, of the fundamental principles of drying, and the basic elements of machine design. These factors, as related to and supported by practical experience, both mechanically and physically, of drying requirements and repetitive performance, comprise the basis for facts to be presented to you and will illustrate the marked improvement in the construction and operation of modern drying equipment.

* James Hunter Machine Co., No. Adams, Mass.

In the field of textile drying, considerable progress and development has resulted in improvement, both in design and performance. The old days of building a box, installing a heater and providing mechanical conveyance of material have been superseded by greatly increased economies in operation and nearly incomparable improvements in design. No claim is made for perfection, but it may be stated with modesty that we are rapidly approaching a standard of efficiency in drying which compares favorably with other manufacturing processes.

Principles of Drying

Drying of textiles is accomplished under atmospheric pressures by means of circulating radiant heat, by induction, and by forced evaporation. Air, unless heated, does not dry. It is merely a conveyor or agent for transmission of the necessary heat; first, by forced draft and filtration to and through the material to be dried, original drying assistance automatically taking place due to the hygroscopic characteristics of the fibres having a normal (or individual) rate of natural diffusion. This action is further stimulated by air velocities through the material, and increasing temperatures setting up pressure differentials in the material, establishing enforced diffusion, which, together with the natural capillary action, present free moisture for evaporation which is then mechanically exhausted.

Before the material to be dried enters the drying apparatus, as much free moisture as possible should be removed by mechanical means; that is, extracted by vacuum, by centrifugal extractors or by squeeze rolls. Surprising as it may seem, it has been experienced on some installations that the mill expected that the material would be delivered to the dryer wringing wet, 100% or more moisture content. The moisture content should not exceed, if possible, 60% dry basis, and the cost of mechanical extraction is far less than the expense of boiler power to do the same work. The amount of moisture in the material is best figured on a percentage of its dry weight. The bone-dry weight is a definite quantity and is preferred, because percentages on original wet weight are variable quantities due to losses through evaporation.

Problematical in the mechanics of drying is the degree of saturation to be attained before exhausting, commensurate with heat economy and rate of production. This feature is well regulated in modern dryers, together with increased efficiency of air circulation. Improved insulation has reduced heat losses. Higher temperatures have been safely used subject to controlled air velocities with no added power consumption, all of which has speeded up production without damage to material and accomplished a reduced drying cost.

Textile materials should be dried in motion. When drying fibres in a fixed position and not being subjected to passing air currents or filtration, the high external temperature and lowered relative humidity would form a dry surface seal, in which case excessive internal heat would be detrimental to the fibres. A positive temperature variable should exist between that inside the material and at the surface. This is a problem to be considered by textile chemists and upon its analysis depend the limits of drying so far as preservation of the strength of fibres is concerned.

Heat transmission increases with the difference in the temperature existing between the heating medium and the material being dried. The

highest temperature the material can physically and chemically withstand determines the minimum drying time, and the relative rate of evaporation is regulated up to the limit of the drying speed of the material, upon which depends the final ratio of production and the efficiency of the drying apparatus.

With particular regard to wool, there are several safety factors throughout the stages of drying. It appears to be nature's protection. It is a generally accepted theory that water is absorbed physically by wool, not combined chemically. Water of hydration, the term applying to the natural moisture regain, is rapidly built up, only slight variations existing, depending upon any differences in relative humidities. This flexibility of wool fibres undoubtedly provides considerable protection for its elasticity and tensile strength, and probably accounts for the safety in piece-carbonizing where fabrics have been passed through the baking section at temperatures of 280° F. and higher.

Of special importance in preserving a degree of moisture content during the operation of drying wool is to preserve its felting properties. The center portion of a wool fibre, the cortex, is a cellular structure of individual cells which are united by a continuous cementing material. If this is broken down, that is, subjected to any chemical change, all subsequent operations are affected, and particularly will it be evident in the fulling; not because the epidermal scale layer is damaged, therefore reducing the physical interlocking properties of adjacent scales, which was the old theory about the felting activities of wool, but rather because of the chemical disintegration of the mucilaginous affinities of the fibres, which the microscope has disclosed as being the felting agent produced by the introduction of moisture, heat and friction. This statement is offered as a possible item of interest for the Research Institute to investigate.

Maximum temperatures of 265° F. to 270° F. have been used without injury to fibres with controlled apportionment, by means of zoning, affording temperature reduction in direct ratio to drying increase. The danger point is approached when the material becomes dried to about 10% moisture content. As the material (stock or cloth) is passed through the dryer with increasing stages of dryness, less heat is (and should be) applied. Excessive surface (outside of fibre) drying or contact with any heated metallic part of the dryer is the cause of physical degrading. So long as vaporization does not over-exceed diffusion and there is even a minimum of moisture present, there will be a protective, resisting film. From about 5% to bone-dry is the line of demarcation between safety and weakened, brittle stock, or tendered fabrics.

Principles of Construction

From the textile manufacturer's point of view, drying apparatus must be of practical value. This depends upon its productive economy, economies of heat and power consumption, minimum maintenance expense, all proportionate to the drying rate, that is, the final output of the apparatus.

Improvement in air circulation is obtained from the use in modern dryers of fans of the centrifugal type. They are distinguished from the disc or propeller fan by the fact that they are capable of operating against high static pressures. Allied with this factor is the proper design of housing for controlling heat losses through leakage and to provide for the

intake of the proper amount of makeup air. These factors have a considerable influence in the economy of steam consumption. A uniform supply of heat must be maintained so that evaporation will occur under a constant temperature which varies according to the material being dried, the type of apparatus, the circulating system and the arrangement and efficiency of the heating elements.

The heating coils should be located away from the material and preferably be made of copper because of its high conductivity and radiant capacity. It is now possible to heat up dryers to full temperature range and cool them down again within the space of a few minutes. They are very susceptible to accurate temperature control, and now incorporated in the design of modern dryers is the feature of temperature zoning.

Changes in the construction of dryers have brought about a lighter but stronger apparatus. In modern tenter dryers, no heat is directly radiated onto the cloth as formerly when the coils were located between the runs of cloth. The new improvements have reduced to a minimum shady goods and spotting. Whereas with direct radiation, seldom could two places of equal or uniform temperatures be found in the machine, this is now under full control. A uniform temperature is maintained throughout the entire dryer and, if wanted, because of the zoning and the controlling, cooling can be effected toward and at the delivery end of the dryer which balances the drying and assists in reconditioning the material for the subsequent operations.

No high velocity air is blown onto the tenter chain nor directly from it; therefore, there is no danger of oil spots on the fabrics. Furthermore, the air is so directed that it holds the cloth on the pins, overcoming a former troublesome feature of continual slippage and slack. Additional frictional resistance and, therefore, more wear is now offered in a new-type chain. The tracks are made of cold-rolled steel welded onto angle iron, greatly increasing both strength and wear and preventing sagging. The entering end of the tracks is long, affording a gradual stretch before subjecting the fabrics to the heat. Automatic selvedge openers have eliminated labor expense. Added to these features is the positive and automatic control with the application of variable speed drives equipped with remote control, automatic cloth guiders, selvedge guards, width adjustments through electrical speed reducers, automatic chain oilers and cleaners, temperature controllers and recorders.

In cloth carbonizing, a former common fault has been overcome: the building up of slack, wrinkling and curling of selvedges. This is now under mechanical control due to the application of a tension-regulating range drive which assures uniformity to each run of goods.

Improvements in stock drying have resulted from duplex control of circulating systems operating on both sides of the drying apparatus. Increased volumes of air are handled through the stock. The counterflow and spiral principle of air currents affords an increased drying capacity as contrasted with older type machines. Direct-connected motor drives obviate shafting, pulleys, belting, etc., and afford considerable reduction in power costs.

The chief indexes of related tendencies in industrial mechanization equally apply to the textile sub-division. These are ratio of wages to value added in manufacture, percentage of machine output partially displacing hand methods, and dollar investment in equipment per wage earner.

From the textile manufacturer's point of view, it has been increasingly difficult, in these times of reduced output, to satisfy the demand on one hand for low capital expenditures which may mean under-equipment, and the demand on the other hand for low unit costs which may mean over-equipment. These are practical variables which enter into the economical equation, but in certain stages of textile production, noticeably drying, there is an attainable balance of reduced costs offsetting obsolescence and antiquated methods at a compensatingly low capital expense.

The Mechanism of Drying Textile Fibres and Fabrics

By LUCIEN BUCK *

IN the textile and allied industries, the dryer is an important manufacturing unit necessary for the processing of raw stocks, yarns and fabrics, utilizing animal, vegetable and synthetic fibres, which may require repeated wetting and drying out before reaching a finished product.

The various textile fibres have different chemical and physical characteristics and being colloidal, hygroscopic substances, are extremely sensitive to changes in temperature and humidity conditions.

Temperature effects on the quality and character of the fibre are relative and are subject to opinion, but in general, the temperatures employed today in the various drying operations have been the result of experience with air conditions existing in a particular type of dryer, rather than the result of any basic research.

Drying technique has shown notable improvement in the diversity of types and methods and the more recent dryers have been designed for high quality of product and provided with automatic control of drying conditions, which have been carefully determined through elaborate experiments. However, in an attempt to remove the moisture quickly and at low first cost, and speed up production, many dryers are forced beyond their proper capacity for quality work, resulting in harsh, damaged or just passable goods.

Factors Determining Character of Drying

In drying any substance, but especially textile fibres, the following factors must be taken into consideration: (1) Origin, characteristics and condition of the material. (2) Moisture content of the material, initial and final, and regain. (3) The time element—or time of exposure. (4) Conditions of the drying medium; *i.e.*, dry- and wet-bulb temperature and relative or absolute humidity of the air. (5) Air velocity over or through the material, and air distribution. (6) The heat supply. (7) The removal of water vapor.

These factors in combination determine the drying rate, quality and quantity of product from any given drying unit. A study of the effect of these conditions on the fibre structure during the drying operation, wherein the textile chemist, fibre expert and drying engineer would cooperate, should be an interesting and valuable subject for research.

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Moisture Content

Moisture or water is present in textile fibres in several forms: (1) Free or excess water held mechanically in the minute channels between the fibres, having a vapor pressure equal to free water. (2) Surface moisture carried as a film or layer, and probably held by surface tension also having a vapor pressure equal to free water. (3) Water of imbibition or "soaked" moisture, which has penetrated the tissue of the fibre, essentially colloidal water which varies with the surface moisture by diffusion and has a vapor pressure less than that of free water. (4) Water of hydration which approaches combination with the substance and exerts no vapor pressure.

The amount of moisture in a material may be stated as a percentage of its original wet weight, or as a percentage of its bone-dry weight. As the bone-dry weight is a definite quantity, this basis of expressing moisture content is to be preferred to that of a percentage of its original wet weight, which varies due to the loss through evaporation.

The moisture may be removed mechanically to a limit of approximately 50% of its dry weight, or by evaporation either through contact with a hot surface or by currents of heated air.

It is hoped the following subject matter will clarify the drying process and point out the significance of wet- and dry-bulb temperature and the physical laws governing the adiabatic evaporation of moisture, as encountered in atmospheric dryers, as well as the effect of drying conditions on the final product.

Mechanics of Evaporation

The wet bulb indicates the temperature of the moisture in the air. The dry bulb indicates the temperature of the superheated vapor mixture. The difference between the two readings, known as the wet-bulb depression, being the heat head available for evaporation or the difference between their respective vapor pressures, may be termed the drying potential or driving force.

By referring to published steam tables it will be observed that the pressure of the vapor in a space saturated with water vapor increases rapidly with the increase of temperature, and also that the density of a cubic foot of saturated water vapor is a definite quantity dependent entirely upon its temperature.

When dry air and moisture are brought together at any temperature, the moisture vaporizes until the vapor pressure is that "corresponding" with the temperature; *i.e.*, that pressure which, according to the steam table, is the pressure of saturated steam at the given temperature. The mixture is then called saturated air, and the water vapor in the mixture may be considered as saturated steam at atmospheric temperature. If, however, the supply of water is insufficient for saturation, its pressure, after it is all vaporized, will be less than that which the steam tables give and the vapor or steam will be superheated. The properties of atmospheric air, therefore, are similar to those of steam. The tendency of all liquids is to pass into the vapor phase.

It is a well known fact that most liquids, if left exposed to the air in an open vessel, even at ordinary temperatures, will gradually disappear by evaporation. It has been shown that, in becoming saturated with vapor, the atmosphere cools to the wet-bulb temperature or temperature of evapo-

ration, and the latent heat of the water or liquid evaporated is exactly equal to the loss in sensible heat of the atmosphere.

The total or atmospheric pressure (taken at 29.92 inches or 760 millimeters of mercury on the barometer, or at 14.7 pounds per square inch) is made up of the combined pressure of all the gases present, but if the total pressure is all produced by the water vapor and there is no air present, the pressure of the vapor in the enclosed space is in equilibrium with the pressure of the water in the material, and no further vaporization will occur. If some of the vapor is removed or some air introduced and the total pressure remains the same, the partial pressure will be lowered (as there is less vapor present, since the air is producing part of the pressure), and vaporization will be resumed and continued until equilibrium is again reached.

It is evident, therefore, that the rate of evaporation of free moisture from a surface is dependent upon the difference between the vapor pressure of the liquid and its partial pressure in the surrounding space, and to maintain vaporization the heat required must be continually supplied, and, in addition, the equilibrium between the vapor pressure of the liquid in the material and the vapor pressure in the surrounding media must be continually destroyed.

The liquid which is on the surface of the material will be readily evaporated; that moisture which is in the interior must diffuse to the surface before further evaporation can occur. These processes go on simultaneously but the rate of diffusion will vary with the nature and construction of the material. In some cases the controlling factor in drying is the rate of surface evaporation, while in others the rate of diffusion of the water from the interior to the surface limits the rate of evaporation, and it is essential to keep in mind the part played by each of these processes to intelligently control the drying operation.

In drying of fibrous materials, the finally fibrous structure which distributes the moisture by capillary action produces a very rapid diffusion of moisture from one point of the sheet to the other. This means it is almost impossible to remove moisture from the surface of the material without having it immediately replaced by capillary diffusion from the center of the mass to the surface.

Mechanics of Air Drying

When a gas or liquid moves over a solid surface, or when a gas moves across a liquid surface, there exists a film of the moving substance upon the surface of the stationary one in which there is practically no motion.

When air is present with the superheated water vapor, the vaporization of a particle from the surface of free water is retarded by the air pressure; or, rather, the stationary film of air in immediate contact with the moisture on the surface of the material which has diffused from the interior, becomes saturated and has a higher vapor pressure, corresponding to the temperature of the surface of the water, thus retarding the diffusion of the vapor to the outside of the film layer where it can be caught up, carried away and disseminated by convection through the mass of surrounding air.

Carrier and Lindsay have shown that the rate of evaporation from a free liquid surface increases the same amount for every 230-feet-per-minute increase in velocity of the air passing over the surface, and also that the

rate of evaporation is approximately twice as great from a surface transverse to the air flow as from a surface parallel to the flow of air; and Sherwood has shown the rate to be proportionate to the 0.6 power of the velocity over a range of 120 to 900 feet per minute with parallel flow. It is apparent that the more rapidly this saturated film is removed, the faster will be the rate of evaporation.

Heated air passing over the moist surface of the material drops in temperature toward the wet-bulb temperature, inasmuch as the evaporation of the water is accompanied by a definite absorption of convected heat. The sensible heat that is apparently lost, due to evaporation, is actually converted into latent heat and, neglecting conduction and leakage losses, the total heat of the air is unchanged during its progress through the dryer.

This heat supply must be maintained in order that evaporation may proceed, and the temperature of the material will remain substantially at the wet-bulb temperature or the temperature of evaporation so long as the moisture on the surface is evaporating freely, due to the large absorption of heat; but as soon as the moisture content of the material falls to about 20% or 15% and from then on until the last traces of moisture are removed, the temperature of the material will gradually rise, approaching the dry-bulb temperature of the surrounding air, and then will correspond when the vapor pressures are in equilibrium.

In order to reduce the drying period as much as possible, and by reason of the fact that heat transmission increases with the difference in temperature which prevails between the heating medium and the material, the highest temperature that the material will stand without injury should be employed, and likewise the greatest air velocity permissible.

In most cases the air should be recirculated or used over again until a certain point of saturation is reached, which varies with different materials and affects the drying rate as well as the final moisture or regain. The partially saturated air should be continuously exhausted to the atmosphere in as near a saturated condition as commercial operation will permit, and an equal amount of fresh air admitted to replace that exhausted. The exhaust air should never become completely saturated, as the drying time would be increased to such an extent as to offset any economies due to saving in heat, and furthermore, in the case of fibrous materials, and on account of their hygroscopic properties, final dryness could never be expected.

Where heat is supplied by air alone, there will be a drop in temperature between the entering and effluent air, the extent depending upon the material being dried, the weight of air circulated and the type of dryer.

After absorbing the first 60% of its vapor capacity, air takes up moisture very slowly to the point of saturation, and it is advisable to provide such a flow of air through the dryer as will not exceed 40 to 50% of saturation as it leaves the outlet.

In the case of evaporation from a free water surface taken place at the wet-bulb temperature, but where evaporation is retarded by the moisture-holding medium, the temperature of evaporation will be somewhat higher depending upon how much the evaporative ability of the air exceeds the ability of the material to transmit water from the interior to the surface. This temperature of evaporation is difficult to measure and varies as drying progresses, so that for purposes of design it is usual to assume it at the wet-bulb temperature.

When the heat is supplied by means other than air, such as radiation or by contact with a hot surface, the wet material temperature is heated above the wet-bulb temperature. The interior vapor pressure is thus increased above that at the surface, the rate of flow of water to the surface is increased and the total drying process is faster even with lower dry-bulb and higher wet-bulb temperatures in the surrounding air than ordinarily used in atmospheric dryers.

It is obvious that when drying at temperatures under 212° the limit of the rate of drying is the rate of evaporation and moisture pick-up from the surface of the material being dried. Above 212° the vapor pressure is a total pressure and susceptible to greater range of drying speed.

Critical Temperatures Defined

Warm moist air is not only better for many substances than dry hot air, but dries them faster. The action of moist heat is less severe, due to the lower drying potential, and in some cases actually improves the product, whereas the same dry bulb with a lower wet-bulb temperature may have harmful effect.

It has been found that, under certain conditions, materials which were considered to have a critical temperature below 200° have been successfully dried at considerably higher temperatures and in a much shorter time.

In general, those materials which dry quite rapidly may be subjected to much higher dry-bulb temperatures than those requiring a longer drying time due to the slower moisture diffusion rate.

Where the critical temperature of the material will allow it, high temperatures speed up drying, both by virtue of more rapid heat penetration of the material being dried and (when combined with rapid circulation of the air carrying the heat) by removing the vapor film from the surface of the material and so facilitating the loss of vapor from the material by vapor tension difference.

The drying process does not proceed at a uniform rate. Usually the first 80% of the moisture can be removed in ¼ to ⅕ of the total drying time; the hard work begins when the last traces of moisture are to be removed; *i.e.*, when the material is wanted in a bone-dry state.

Under constant drying conditions, as long as the surface of the material has surplus moisture the rate of drying continues "constant" down to some definite water or critical moisture content (which in most textile fibres is around 33%) with no harmful rise in temperature, and then the drying rate begins to fall or decrease with the capillary diffusion of the moisture, diminishing as dryness is approached with a corresponding increase in material temperature, the ultimate value depending upon the air conditions.

In case the wet material is initially at some temperature other than the equilibrium temperature prevailing during the "constant rate" period, an adjustment period occurs during which the material is warmed or cooled to the equilibrium temperature.

The harmful effect of temperature on the finish or physical structure of a fibrous material is a function of time of exposure. Wet pulp sheets have been subjected to a temperature of 1900° F. without injury until a certain moisture content was reached (around 80%). Dry cotton cloth is singed without damage if travelling at high speed over a gas flame. The

"hand" of silk fabrics is said to be improved by a quick and short exposure to the radiant energy of gas flame while containing surplus moisture. One plant is drying rayon fabrics by using the products of combustion from an oil burner at high temperatures without apparent injury. Cotton goods are dried in a superheated vapor, approaching 300° F., and tests have indicated that the various textile fibres with normal regain do not scorch when in contact with a hot-iron surface for a period of five seconds, where the temperature does not exceed 350° F.

It has been shown that the mechanics of the drying process are fully understood, and it is evident that machine output can be increased without material detriment to the fibres by utilizing higher temperatures while rapid evaporation prevents overheating until the critical moisture is reached, and then removing the diffusion moisture in a properly conditioned atmosphere to maintain the natural characteristics and proper "hand" of the finished product.

Importance of Air Movement in Drying

By B. M. JONES*

IN the following discussion, air movement covers air circulation, air recirculation and air distribution. The factors influencing drying to the greatest degree are: temperature, humidity, and air movement. Practically, all three are interdependent. However, the results of our experience show that air movement is the greatest single factor. Without air movement, there would be very little drying. As proof, consider an enclosed dryer with no movement of air. The dryer could be heated and some water would be evaporated, but without air movement the atmosphere would rapidly reach the saturation point, and evaporation would stop.

While temperature is an important factor, it is greatly influenced by air movement. No temperature can be considered safe for a certain fabric without taking into consideration the movement of air, and the amount of moisture present in the cloth. In continuous dryers, this fact is taken into consideration. For instance, with the counterflow system of air circulation, used in most "Hurricane" dryers, the wet material at the feed end encounters warm and humid air which has already passed through the major portion of the dryer. Due to the high moisture content of the material at this point (the feed end), rapid evaporation prevents it from over-heating, even though the temperature is higher than the dry fabric would itself stand. As the material becomes dryer and the cooling effect of the evaporation is lost, the temperature must be lowered to a point at which it will not injure the particular fabric being processed.

Consider, for a moment, a tenter dryer built a few years ago. The machine has heating coils between the passes of cloth, an insulated housing, fans for the cross circulation of air, and is in excellent operating condition. The faults of this machine are best illustrated by the experience of a certain manufacturer of plush fabrics. He found that goods coming from the dryer had the pile baked. This condition could be traced to the cross circulation of air. Obviously, the pile or surface of the cloth dried first and became not only dry but actually baked in the dryer, while the more dense part of the fabric was not yet thoroughly dry. This condition was so bad

* The Philadelphia (Pa.) Drying Machinery Co.

in certain instances that the cloth would actually catch fire after leaving the machine, unless it had cool air blown through it to cool it off.

Sometimes this machine would be stopped with cloth in it. The cloth would naturally sag and come very close to the steam coils and be exposed to a high degree of radiant heat. Usually, the result was shaded goods. If the cloth was dyed later, it would dye a different shade in the center of the piece from what it did at the sides. If the goods had already been dyed, the color in the center was usually affected. No data were obtained on the tendering effect of the heat, but it is easy to imagine that it was considerable.

In the instance just mentioned, the air temperature was 230° F. throughout the dryer. Some of the latest tenter dryers operate at the same average temperature. However, in the new "Hurricane" dryer, the temperature is high at the start (when the cloth is wet, and evaporation keeps the cloth cool), while at the delivery end the temperature is much lower. Also, an entirely new principle of air circulation is used. Heated air, instead of being blown across the cloth, is blown directly through it. This "through circulation" approaches very closely to what we may consider ideal air distribution; *i.e.*, every individual fibre comes in contact with live, heated air and, therefore, every fibre becomes dry at a uniform rate.

This principle allows us to use a fairly high initial temperature and allows us to finish at a low temperature. In some cases, machines are built to deliver the goods at very nearly room temperature. The cool, delivery temperature of this machine is brought about by the entrance of cool, fresh air near the last pass of the cloth. This provides an additional economy, for an exchange of heat from the hot cloth to the cool air is effected. This system results in uniform drying and also results in the fabric being in excellent condition when dried.

The rapidity with which drying is accomplished depends largely on the velocity and pressure of the heated air. Therefore, in order to get maximum efficiency, it was necessary to develop a unit which would supply hot air under pressure and direct it uniformly through the fabric. The heart of this unit is the fan. The old-style, disc fans would supply the volume of air, but they would not supply air under sufficient pressure. It was necessary, therefore, to develop a fan capable of meeting the particular requirements.

The large amount of research and experimentation occasioned by the rapid development in the airplane industry has resulted in a much better understanding of the laws governing air flow. This information, supplemented by work in our Research Department, resulted in the development of a fan suited particularly for dryer use.

The fan now in use is of the axial-flow type, with radially tapered blades. The blades are curved in the form of the "air foil," the shape so widely used in airplane construction; the shape and curvature being such that the blade pitch varies throughout the length of the blade. This type of fan gives uniform air flow at all parts of the fan area, eliminates all back flow and maintains high mechanical and static efficiency throughout the entire dryer. The blade shape is admirably suited for high speed operation from direct-connected motors; the light curved blade, tapering towards the end, results in a concentration of the weight near the center, rather than the tip, thus reducing centrifugal and vibration stresses to a minimum.

The heating unit of this machine is of the extended-surface type and is kept away from the cloth. Therefore, there is no chance of leaks damag-

ing the cloth, or of the fabric coming in too close contact with the heating coils.

Following along the thought that uniform air distribution is essential, the inside of this machine is made as nearly streamline as possible. The interior of the dryer housing presents a flush wall surface, with no structural members projecting so as to interfere with air circulation or to collect dirt and flock. Streamline baffles are also provided to direct the air and reduce eddy currents.

This new dryer will in many instances increase production by several hundred percent and it will also deliver the material in better physical condition. The one principal factor making this possible is "through circulation." "Through circulation" means uniform drying. Uniform drying means fast drying, and fast drying means maximum production and greatest efficiency. A high temperature is used when the goods are wet, and evaporation can provide the cooling effect. As the cloth becomes dryer, the temperature drops to a point where it cannot injure the fabric. Every fibre becomes dry uniformly, thus eliminating the possibility of baking the surface of the material.

It would seem from what has been said already and from what will undoubtedly be said in the open discussion, that there is a real need for scientific research in many phases of the drying of textiles. I would like to say now that The Philadelphia Drying Machinery Company would feel privileged to have the opportunity of co-operating to the fullest extent with the United States Institute for any research along these lines.

Obituary

Claxton Monro, chief chemist of the American Woolen Company, died at his home in Andover, Mass., May 12, after a long illness at the age of 51. He was a native of Providence, R. I., a graduate of the Boston Latin School and Harvard University. He had been associated with the American Woolen Co. for 27 years, and since 1930 as chief chemist. He was the representative of this company's contributing membership in U. S. Institute, and was a charter member and member of the research committee of the A. A. T. C. C. He is survived by his wife, three sons and his father, Rev. H. Usher Monro.

Joseph Bancroft, chairman of the board from 1928 to 1933 of Joseph Bancroft & Sons Co., Wilmington, Del., died of pneumonia at the Homeopathic Hospital in that city May 6, after a short illness. In his 60th year, he had been affiliated with that company throughout his business life, and was also a vice-president of the Eddystone Manufacturing Co., a director of the Wilmington Trust Co., the Delaware Railroad and the Farmers Mutual Fire Insurance Co., and had served as president of the Huntingdon & Broadtop Mountain Railroad. He was prominent in Masonry, a Rotarian and an Elk. In 1924 he was a candidate for governor of his state on the Democratic ticket, and was a life-long member of that party. His clubs and societies were numerous, particularly those devoted to the sciences and the fine arts. He was graduated from Massachusetts Institute of Technology in 1898. He was a charter member of U. S. Institute for Textile Research, and a valued director and member of the Executive Committee. He is survived by his wife.

Pebble Formation in Rayon Crêpe:

A Discussion of the Mechanical Forces Involved

By R. L. STEINBERGER *

Fellow of the Textile Foundation

THE writer has been invited to look into the methods of manufacture of rayon crêpe, then, from the point of view of a physicist somewhat familiar with the mechanical properties of rayon filaments, "develop a rational explanation of crêping."

Through the co-operation of Dr. H. DeWitt Smith † of the A. M. Tenney Associates, the writer obtained introductions to several New England rayon textile plants and was pleased to find very cordial co-operation of the mill men who were willing to go into great detail in the description of their processes and to submit samples of both good and defective fabric for laboratory examination.

In bare essentials of machine operations the manufacture of rayon crêpe is an extremely simple series of processes as compared with the technologies of some of the more complex industries such as, let us say, the electrical industries of telephone and radio manufacture. In the electrical industries precise mathematical engineering can be used because the physical phenomena involved are such as to permit precise and reproducible measurement. This is the absolute opposite of the situation encountered when one tries to apply exact mathematical methods to the solution of textile problems where we are brought face to face with such notoriously incorrigible physical effects as frictional force, plasticity and all the other mechanical properties of solids outside the elastic range, if such a range indeed exists at all in textile materials.

* Dr. Steinberger is working under the direction of Prof. P. W. Bridgman, Harvard University, Cambridge, Mass.

† Vice-chairman U. S. Institute's Research Council, and member joint committee of Throwsters Research Institute and the A. A. T. C. C. in charge of study on rayon crêping.

Take now the passage of a rayon yarn through the soaking, throwing, weaving, etc., operations of crêpe manufacture. We know in a general way what the mechanical phenomena of elasticity, yield, plasticity, creep, torsional energy of twist, etc., are doing. But as yet we have little quantitative knowledge which may be checked by instrumental means. It is practically hopeless to refer the gross mechanical state of the yarn back to the fundamental atomic, molecular, or even to the crystalline or micellar state and apply precise mathematical reasoning. What we can do, however, is to make measurements of tensile strength, torsional energy, etc., on the yarn as we find it in process or in the fabric and look for correlation, if any exist, between the type of fabric defect and these measurements.

In such an unexplored field it is futile to attempt to set up a physical explanation of crêping without the support of experimental evidence. Such theorizing would be taken for just what it is—mere opinion. In the following, therefore, the results of some preliminary experiments will be included to support the opinion that we should begin our attack on the explanation of crêping by a study of the storage and release of torsional energy in the yarn and the pebble produced in the finished fabric.

In the conference on Rayon Crêping Problems, held on November 14, 1935, by the U. S. I. T. R.* the main operations in the manufacture of rayon crêpe were listed as follows: (1) Soaking of the rayon skeins; (2) Twisting or Throwing; (3) Steaming or Setting; (4) Copping; (5) Weaving; (6) Finishing ("boil-off"). In each operation there are several controllable (*i.e.*, independent) variables. Adding the essential operation of drying we may expand this list of operations into a table of 20 independent variables. Only those variables of obvious bearing on the problem are listed. Others are conceivable. Assuming that the condition of the resulting fabric is influenced by every one of the 20 variables the explanation of crêping seems to be a complex problem indeed.

A Feasible Basis of Study

In setting up an explanation of crêping and crêpe defects two courses are open: We may outline a comprehensive program of research wherein

* *Tex. Rsch., VI,* 2, 69–76 (1935).

a series of crêpe fabrics are made and variable No. 1 of Table 1 is changed, all the others being held fixed. Then another series of crêpes are made with changes in variable No. 2 only, and so on through the list. It would not be possible to hold the fixed variables so precisely constant that the effect of variation in one alone would persist throughout all operations.

TABLE I

List of Possible Variables in the Manufacture of Crêpe Fabrics

	Operation	Ind. variable	No. of variable
1.	Soaking in water solution or emulsion with two dispersed components, say oil and size	% oil	1
		% size	2
		Temperature	3
2.	Drying	Temperature	4
		Duration of drying	5
		R.H. of drying oven	6
3.	Twisting or throwing	Tension	7
		Turns per inch	8
		R.H. of throwing room	9
4.	Steaming or setting	Temperature and R.H.	10
		of steam chamber	11
		Duration of steaming	12
5.	Copping	Tension	13
		R.H.	14
6.	Weaving	Tension of warp	15
		R.H.	16
7.	Finishing, *i.e.*, boil-off	Composition and	17
		temperature of bath	18
		Duration	19
		Mechanical handling method	20

The other course, and to the writer the only feasible one, is to consider, first, the obvious large effects, make a shrewd guess or hypothesis as to the probable effect of one essential detail of operation, then build up the hypothesis, or refute it by careful measurements.

Only one operation, namely throwing, is distinctive and uniquely characteristic of crêpe manufacture. Certainly we cannot make crêpe having pebble without the throwing operation. Throwing puts into the yarn a torsional energy which is partially released in the final finishing operation (No. 7, Table I). The friction of woven fabric prevents any considerable rotation of the yarn about its own axis. But in the usual boil off, fabric skrinkage is not restrained and the twisted yarn gets rid of some of its torsional energy by throwing up kinks. The kinks are the direct cause of the fabric distortion called pebble.

Having decided that the torsional energy in the yarn is the prime mover in pebble formation, we must look for a correlation between the torsional energy and the height or amplitude of the pebble waves. This means the study of a crêpe fabric in which identical yarns produce areas of pebble of a distinctly different type; *i.e.*, a defective crêpe fabric. A typically defective crêpe fabric may be described as follows: Let us assume that the fabric is running warpwise across the inspection board. The fabric will for many yards be satisfactory as far as uniformity of amplitude and wave length of pebble are concerned; then suddenly a band of higher pebble will appear running parallel to the filling across the entire width of the goods. Warpwise the band may have any width from a few inches to several yards. The borders of the band are sharply defined. The transition from normal to the high pebble can usually be localized in one or two filling threads. In a dyed fabric the change in pebble may give the illusion of imperfect dyeing. Data collected in some preliminary experiments will now be presented to show that there is a connection between the torsional energy in the thrown filling yarns and the amplitude of the pebble which the yarns produce.

EXPERIMENTAL

Description of Samples

Four samples were examined, consisting of three yards of fabric and two quills of Z and S twist yarn. The weaves of the fabric samples were all the same and all viscose, with two ends of Z alternating with two ends of S twist in the filling. The warp was untwisted viscose. The individual differences are described in Table II.

TABLE II

Sample Description

Sample No. 1.—White finished fine pebble crêpe. On one half the pebble was even and very fine—the result aimed at by the weaver. On the other half the pebble was high but quite even. The transition between the high and the low pebble areas was very sharply localized to a few filling yarns and ran strictly parallel to the filling.

Sample No. 2.—Two quills of the thrown and set viscose yarn, one Z, the other S twist, from which Samples 3 and 4 were woven.

Sample No. 3.—A yard of the greige goods from which Sample No. 4 was made.

Sample No. 4.—A yard of dyed and finished crêpe with a uniform pebble as great in amplitude as the pebble in the defective area of Sample No. 1.

The pebble formation in Samples Nos. 1, 3 and 4 was caused by the release of torsional energy in the filling only.

Tests on Sample No. 1

A small swatch, 4 in.-long fillingwise by 2 in.-wide warpwise, was cut from the fabric with the well defined boundary between the coarse and

fine pebble areas running down the center parallel to the filling. All the warp yarns, except the last dozen or so at one end, were carefully teased from the swatch. All the filling yarns were thus freed for a length of over three inches but retained their relative positions. By this means the filling yarns were removed from the fabric with the smallest possible pulling. Overstrain is thus avoided. The thrown yarns in the finished fabric when dry are in a quiescent or equilibrium condition. This equilibrium can readily be upset by very slight overstrain, with resultant partial untwisting which destroys the accuracy of subsequent torque measurements. Handling with moist fingers, or changes in relative humidity, will also upset the equilibrium.

A sensitive torsion balance was then constructed to measure the torque exerted by the filling yarn when the internal torsional energy was set free

Table III

Torque released in filling yarns from Sample No. 1 when immersed in water at 23° C.

Yarn No.	Torque value in degrees deflection							
	Defective or high pebble fabric				Good or low pebble fabric			
	S Twist	% Deviation from Avg.	Z Twist	% Deviation from Avg.	S Twist	% Deviation from Avg.	Z Twist	% Deviation
1			89.5	+4.4			85.5	+1.2
2			85.0	−0.8			82.7	−2.1
3	103.5	−0.1			87.5	−3.1		
4	106.0	+2.3			90.0	−0.3		
5			88.0	+2.7			86.0	+1.8
6			85.0	−0.8			83.5	−1.2
7	101.0	−2.5			91.5	+1.3		
8	88.5	−14.6			91.0	+0.8		
9			87.6	+2.2			85.0	+0.6
10			89.0	+3.9			85.0	+0.6
11	105.5	+1.8			88.5	−2.0		
12	106.0	+2.3			89.5	−9.0		
13			84.5	−1.4			82.0	−3.0
14			80.0	−6.7			88.0	+4.1
15	102.0	−1.5			91.5	+1.3		
16	105.5	+1.8			89.5	−0.9		
17			82.5	−3.7			84.5	0
18			85.5	−0.2			83.0	−1.8
19	107.5	+3.9			94.5	+4.7		
20	110.5	+6.9			89.5	−0.9		
Ave.	103.6		85.7		90.3		84.5	

In defective pebble, avg. S twist 21% greater than average Z twist.
In good pebble, avg. S twist 6.8% greater than Z twist.
To convert degrees deflection to torque in gram centimeters, multiply by the calibration factor 2.31×10^{-4} (Tables III, IV, V and VI).

by immersion in water at room temperature (about 23° C.). All measurements of torque were made at this temperature. The torsion balance was designed in a manner obvious to anyone familiar with physical instruments. It will be described in detail at a later time. The results of the torque measurements on Sample No. 1 are collected in Table III. The yarns were taken serially starting with yarn No. 1 at the edge of the swatch and working toward the transition line.

The reader may be somewhat puzzled by an apparent change in terminology. The torsional energy stored in the thrown yarn has been singled out as the cause of crêping, but now the torque has taken the place of torsional energy. A moment's consideration will, however, show that since we are interested only in the available torsional energy set free by wetting the yarn, the torque exerted by the wet yarn is proportional to this available energy. Just as in the case of a stretched spring the energy stored in the spring is proportional to the force exerted by the spring.

Examination of Table III brings out at once the important fact that the unbalance between torques in the Z and S yarns is greater in the defective or high pebble area than in the low pebble area. The unbalance in the high pebble area amounts to 21% S greater than Z, while in the low area the unbalance is in the same direction amounts to only 6.8%. It is apparent that the higher the degree of torque unbalance between the Z and S yarns, the higher will be the pebble and we may therefore be tempted to jump to the conclusion that a perfect balance between Z and S torque will give a fabric devoid of pebble. The balance can, however, never be better than the random fluctuation from yarn to yarn and from point to point along the length of the same yarn. In the defective fabric data of Table III random fluctuations of torque from the average run from + 6.9% to — 14.6% S, and from + 4.4% to — 6.7% Z. In the good portion the range is from + 4.7% to — 9.0% S, and from + 4.1% to — 3.0% Z.

There is one rather serious objection to the conclusions drawn from Table III: The forces which raise the pebble in the boil-off reside in the thrown yarn of the greige goods. The torque in the thrown yarn of the finished goods is what is left over after the greige-goods torque has expended energy in raising the pebble. But the boil off causes a general reduction in all torques and a smoothing out of variations, so that if the S torque is found to be greater than the Z torque in the greige goods it will remain greater in the finished goods and the Z and S differences will be reduced. Our conclusion that the height of pebble depends on the degree of torque unbalance still holds. Unfortunately, no greige goods from which Sample No. 1 was made was available for examination, but the tests on Samples Nos. 3 and 4 to be described later (Tables V and VI) support the statements in this paragraph.

Tests on Sample No. 2

The Z and S twist yarn from the two quills were tested for torque released when the yarn was immersed in 23° C. water. The results are given in Table IV. Tests were made at, roughly, one foot intervals along the length of the yarn. Note the considerable fluctuation in torque from point to point. Even if the average torques were equal, rather than 7.8% out of balance, the fluctuation alone would induce a pebble greater than that of the good fabric of Sample 1, Table III, for at any point in the

TABLE IV

Variation of yarn torque at one foot intervals of length. S and Z twists from Sample No. 2, filling for Samples Nos. 3 and 4.

Yarn No.	Torque value in degrees deflection when yarn is immersed in water at 23° C.			
	S Twist		Z Twist	
	Degrees Torque	Devia. from Average	Degrees Torque	Devia. from Average
1	149.0	+1.9	159.0	+0.3
2	142.5	−2.6	157.0	−1.0
3	154.5	+5.6	152.0	−4.1
4	155.0	+6.0	170.0	+7.2
5	154.0	+5.3	167.5	+5.6
6	151.5	+3.6	153.0	−3.5
7	145.5	−0.5	156.0	−1.6
8	112.0	−23.3	148.5	−6.4
9	151.5	+3.6	161.5	+1.8
10	147.0	+0.5	161.5	+1.8
Ave.	146.3		158.6	

Average S torque is 7.8% less than average Z torque.

finished fabric taken at random there is a good probability that the S and Z torques would not balance.

Miscroscopic examination of the thrown yarn goes one step further in explaining the fluctuation of torque along the length of the yarn. In a perfect yarn we would expect all fibres to follow uniform spirals enclosed in a smooth and uniformly cylindrical yarn outline. Low-power magnification reveals considerable departure from uniformity of twisting. The "cork-screw" effect is particularly prominent. In the perfect twist the fibres form a symmetrical group of spirals all having the same axis, and the axis coincides with the central filament of the bundle of fibre composing the yarn. At the "cork-screw" points *all* filaments take a notion to choose one of the *outside* filaments of the yarn bundle as axis, for a distance ranging from a half turn to one or two turns. It would be interesting to study the defect further. It is difficult to see how it can occur in yarns the manufacture of which has been carefully controlled.

Tests on Sample No. 3 (Greige Goods)

In Table V are listed torque measurements on the greige goods, the filling yarns of which are represented by Sample No. 2. Note particularly that the average S torque is only 4.9% greater than the average Z torque. Judging from the 21% unbalance in the defective part of Sample 1, Table III, the 4.9% unbalance cannot produce a very high pebble. But the greige goods when finished does give a pebble as high as the defective part

of Sample No. 1. The high pebble must be due to the large deviation from the average torque in both Z and S yarns (Table V).

TABLE V

Torque released in filling yarns from the greige goods of Sample No. 3 when the teased out yarn is immersed in water at 23° C.

Yarn No.	S Twist		Z Twist	
	Torque in Degrees	% Deviation from Average	Torque in Degrees	% Deviation from Average
1	143.0	+5.3		
2	149.5	+10.0		
3			128.5	−0.7
4			81.0	−37.4
5	149.5	+10.0		
6	115.0	−15.2		
7			131.0	+1.2
8			138.5	+7.0
9	152.0	+12.0		
10	113.5	−16.4		
11			140.0	+8.2
12			134.5	+3.9
13	149.5	+9.5		
14	148.0	+9.1		
15			136.5	+5.5
16			134.5	+3.9
17	86.5	−36.0		
18	152.0	+12.0		
19			131.5	+1.6
20			137.5	+6.3
Ave.	135.7		129.4	

Average S is 4.9% greater than average Z torque.
Note that the deviations of the individual measurements are greater than the 4.9% difference between average Z and S.

Test on Sample No. 4 (Finished Crêpe)

Here again we have a good balance between the average Z and S torque. Note particularly that the averages of both Z and S torques have been reduced and reduced to practical equality, and that the fluctuations also have been reduced. This finished fabric has a rather high pebble which, unlike that in the defective Sample No. 1, cannot be referred to an unbalance of average torque, but must be related to the random fluctuation of torque which is large in the greige goods. Comparing Table V (greige goods) with Table VI (finished goods) we get a rough measure of the decrease in torque in the boil off. The decrease is to be expected. Distortion of the fabric permits a greater percentage release of the high torques than of the low torques.

TABLE VI

Torque released in the filling yarns in the finished crêpe of Sample No. 4 when the yarns are teased out and immersed in water at 23° C.

Yarn No.	S Twist		Z Twist	
	Torque in Degrees	% Deviation from Average	Torque in Degrees	% Deviation from Average
1	118.0	−1.5		
2	113.0	−5.7		
3			129.0	+7.4
4			123.5	+2.8
5	122.5	+2.3		
6	122.5	+2.3		
7			118.0	−1.7
8			127.5	+6.2
9	118.5	+1.1		
10	120.5	+0.8		
11			117.5	−2.2
12			113.5	−5.5
13	125.5	+4.8		
14	117.5	−1.9		
15			125.5	+4.5
16			118.5	−1.3
17	119.5	+0.3		
18	120.5	+0.6		
19			116.0	−3.4
20			112.0	−6.7
Ave.	119.8		120.1	

Average S torque is 0.25% less than the average Z torque.
Note that the deviations of the individual measurements are greater than the 0.25% difference between the averages.

Permanence of Torque Exerted by a Wet Yarn

The two quills of thrown viscose yarn (Sample 2, Table II) were received several months ago when the writer received the first and unofficial word that the crêpe problem would be opened. A rather crude torsion balance was set up at once and a piece of the thrown yarn was attached. The untwisting tendency of the yarn acted against the torque of a rather stiff wire so that the resulting untwisting was exceedingly small, amounting to only 0.9°. The torsion of the wire was measured by the use of an optical lever. In the improved torsion balance constructed later, torque is indicated directly on a needle so that untwisting may amount to as much as 180°, depending on the suspension wire used.

Table VII shows the permanence of torque when the yarn is kept immersed in water at 23° C. When the bath was removed, drying caused the internal strains to set again and the torque reading fell to zero. If

TABLE VII

Torque released in the left twist yarn of Sample No. 2 when immersed in water at room temperature for many hours

Reading No.	Elapsed time in hours	Torque in arbitrary scale reading mm.
1	0	29
2	1	29
3	3	27
4	20	27
5	74	24
6	75	24
7	91	24
8	163	24
9	355	24
10	405	24
11	434	23
12	1202	24

1200 hours = 50 days.
29 mm. equivalent to only 0.92° untwisting.

considerable untwisting were permitted, say 90° to 180°, as in the improved torsion balance, the return will not be quite to zero. At each torque measurement the yarn was dried for a few minutes to check the zero. At all the intervening time the yarn remained submerged. The torque remained steady and almost constant, falling only about 17% over the whole time of observation (50 days). In both torsion balances the full torque is released in less than ten seconds after immersion in room-temperature water, then when the water bath is removed quickly there is a small and rapid but unmistakable increase of torque, followed by the slower decrease due to drying. It would be an interesting undertaking to follow these and other similar phenomena further.

The torque stored in the yarn by throwing and setting has three unique characteristics: (a) it is released very quickly when the yarn is immersed in the simplest possible reagent, namely, water at room temperature; (b) if the yarn is kept from untwisting the torque persists for long periods; (c) in cycles of alternate wetting and drying the torque is perfectly reversible between 0 and the maximum amplitude. *These three phenomena indicate that the torque is a fundamental characteristic of the material of the fibre itself and cannot readily be influenced by any treatment mild enough not to permanently injure the yarn, and that the influence of the composition of the soaking and boil-off solutions, or the duration of the soaking, drying and boil-off operations will have only a secondary effect on the resulting pebble of the finished crêpe.*

Conclusions

Under this heading the conclusions drawn from the experimental data of Tables III to VII inclusive will be presented as if they were statements of well established fact, whereas the measurements from which they are drawn are not extensive enough to do more than indicate the trend the

investigation should take in order to lift these conclusions from the status of mere opinion.

(A) The critical step in the manufacture of crêpe, in so far as amplitude (coarseness) and uniformity of pebble are concerned, is the mechanical operation of inserting the high twist (throwing).

(B) The amplitude of the pebble depends upon the degree of balance between the torques exerted by the Z and S twist yarns when the fabric is wet by the first finishing solution. The greater the torque unbalance the greater the amplitude of the pebble.

(1) Unbalance may arise from two causes: The thrown yarns may be very uniform as to variation of torque within one and the same yarn, but the Z and S yarn torques may be different.

(2) The average torque of the Z and S yarns may be equal, but there may be a large variation of torque from point to point in one and the same yarn.

(C) Uniformity of pebble depends upon the distribution of torsional energy in the thrown yarns as measured by the torque released in the boil-off.

(1) If the Z and S yarns are individually uniform in torque, and differ by a constant and considerable percentage over a given area of fabric, the pebble will be uniformly high in that area.

(2) If the average torques exerted by the Z and S yarns are equal but the variation of torque along the yarns is regular, the resulting pebble will be uniform.

(3) If the yarns are uniform and the torque unbalance between the Z and S yarns is zero, we will get a very fine pebble.

(D) The torque released in a thrown and set viscose yarn when immersed in water seems to be an intimate property of the material from which the yarn is made, and as such will probably not be much influenced by wide fluctuations in soaking and boil-off solutions which do not react chemically with the fibre.

The results presented here do not go farther than to say that the amplitude of pebble depends upon the condition of balance of the available torsional energy stored in the Z and S thrown yarn, and that the uniformity of pebble depends on the uniformity of distribution of points of unbalance. The desire of the manufacturer is to make uniform crêpes with pebble of predictable amplitude. Before this can be done a whole series of questions must be answered, the first of which is: What governs the amount of torsional energy stored in the yarn; is it turns per inch, denier, filament number? The second question may well be: Why is the torque not uniform in one and the same yarn? The presence of "cork-screw" regions in some yarns may point to the answer of the last question.

The general conclusion is that the solution of crêpe problems can more profitably be looked for by systematic and logical tracing down probable causes for very specific defects, rather than in a broad and comprehensive research program which would involve much expense and a long period of time to bring to a conclusion.

Abstracts

This section is compiled under the direction of the Committee on Abstracts and Bibliography: Prof. E. R. Schwarz, Chairman, M. W. Weiss, Dr. Irving J. Saxl and C. H. Clark.

I. Fibres (Synthetic and Natural) and Fibre Analysis

Viscose Rayon: Strengthening of. A. Razumeev and V. Barakov. *Iskusstvennoe Volokno* (Artificial Fibre), 1935, V. 6, P. 118–27.

A review of literature with more than 20 references. (From *C. A.*, 1935, V. 29, Col. 6431.) (W)

Rayon from Silk Fibroin and Other Animal Albuminous Substances. Jos. Buchkremer. *Monatsh. Seide Kunstseide*, 1935, V. 40, P. 324–32.

A historical review and discussion of patents and articles. Among the solvents for silk fibroin are mineral acids, particularly H_3PO_4, concd. salt solns., combined solvents, Cu and Ni oxide, NH_3, liquid NH_3 and formic acid. (From *C. A.*, 1935, V. 29, Col. 7083.) (W)

Sericin: Colloid Properties. H. Kaneka. *Bull. Chem. Soc. Japan*, 1934, V. 9, P. 510–20 (through *Chem. Zentr.*, 1935, ii, P. 1189); *J. T. I.*, Dec. 1935, P. A648. (C)

Silk Fibroin. W. Traube, H. Härting, V. Senftner and S. Kell. *Ber.*, 1935, V. 68B, P. 1405–8.

Silk fibroin gives the biuret reaction. Its degradation by various means is described quantitatively and qualitatively. (From *C. A.*, 1935, V. 29, Col. 7358.) (W)

Silk Lousiness Now Detected and Graded. *Am. Silk. & Rayon J.*, Dec. 1935, P. 25.

Early researches under the auspices of commissions for studies on silk, and experiments and tests by experts to determine the causes of the imperfections which are now classified. (C)

"Stapelfaser." H. Fischer. *Spinner u. Weber*, 1934, V. 52, No. 31, P. 5–6.

"Stapelfaser" or vistra is a short-fibred rayon which is said to be just as good and which can be mixed with cotton, wool and linen. It is a mechanically manufd. rayon said to be superior to cotton in several respects.

Its filament is 1.2–1.5 denier. Wollstra is a mixt. of wool and vistra. (From *C. A.*, 1935, V. 29, Col. 8345.) (W)

II. Yarns and Fabrics

RAYON FABRIC: NON-CREASING. Otto Pennenkamp. *Deut. Wollen-Gewerbe*, 1934, V. 66, P. 327–9.

A discussion dealing with the making of this product and the various precautions to be observed during the sep. stages of its manuf. (From *C. A.*, 1935, V. 29, Col. 8345.) (W)

RAYON: STRENGTH AND EXTENSIBILITY. A. Zart. *Monatsh. Seide u. Kunstseide*, 1935, V. 40, P. 15–17, 61–3.

A general discussion of the influence of structure, of moisture and of swelling on the strength and extensibility of rayon, methods of determining these properties by means of the Schopper tester, the need for revision of the German standard conditions of testing, the practical value of strength, extensibility and elasticity data and load-extension diagrams, and the examination of rayon yarns in cases where over-stretching is suspected. (From *J. T. I.*, June 1935, P. A317.) (C)

RAYON WARPING AND SIZING. M. Werler. *Kunstseide*, 1935, V. 17, P. 124–30.

Various precautions to be taken in the warping and sizing of rayon in different forms, the choice of suitable sizes, and the advantages and disadvantages of linseed-oil sizes are discussed. (From *C. A.*, 1935, V. 29, Col. 7665.) (W)

RAYONS: RESISTANCE TO CREASING. F. Ohl. *Kunstseide*, 1935, V. 17, P. 351–4.

A general discussion of the creasing properties of rayons and their dependence on the nature of the material and the treatments to which it has been subjected, and of finishing processes for increasing the resistance of rayons to creasing based on the use of synthetic resins or polymerized unsaturated fatty acids. (From *J. T. I.*, Dec. 1935, P. A639.) (C)

RING FRAME "BALLOON": THEORY. A. Nau-Touron. *L'Ind. Text.*, 1935, V. 52, P. 233–5, 287–8.

A theoretical study in which equations of equilibrium are deduced for the thread balloon on ring spinning and doubling frames. (From *J. T. I.*, Oct. 1935, P. A490.) (C)

III. Chemical and Other Processing (Not Otherwise Classified)

SKEIN YARN MERCERIZATION: INFLUENCE OF THE DEGREE OF STRETCHING ON THE PHYSICAL PROPERTIES, PARTICULARLY THE HEIGHT OF THE LUSTER NUMBER OF COTTON THREADS DURING. F. Kurtz and C. Kurtz. *Monatschr. Textil-Ind.*, 1935, V. 50, P. 165–7, 193–4; *C. A.*, 1935, V. 29, Col. 7666. (W)

SOAPS AND EMULSIFYING AGENTS: PROPERTIES. A. Chivala. *Textilber.*, 1935, V. 16, P. 509–11; *J. T. I.*, Oct. 1935, P. A505. (C)

SOURING OF DESIZING LIQUORS. G. Rordorf. *Tex. Col.*, June, 1935, P. 418.

Preventing the rapid growth of lactic acid bacteria and assuring the stabilization and efficiency of desizing liquors. (C)

STAIN REMOVAL: MODERN METHODS OF. Pegasus. *Tex. Col.*, Nov. 1935, P. 729. (C)

STAINS: THEIR DEVELOPMENT, PREVENTION AND REMOVAL. F. C. Pratt. *Tex. Col.*, May, 1935, P. 337. (C)

STENCIL PRINTING OF TEXTILES. A Franken. *Z. ges. Textil-Ind.*, 1935, V. 38, P. 378–9, 390–1.

The prepn. of the printing stencil is cheaper than that of the engraved Cu roller and with the stencil there is no waste of dye, as there is in machine printing. Methods of making stencils and the processes of printing with them are described. Vat dyes, principally, are used. (From *C. A.*, 1935, V. 29, Col. 6764.) (W)

STREAM POLLUTION AND TEXTILE WASTES. C. D. Blackwelder. *Tex. Exporter*, 1935, V. 15, No. 103, P. 25–7; *J. T. I.*, Dec. 1935, P. A644. (C)

SUBSTANTIVE DYEING: PRESENT-DAY VIEWS ON. W. Weltzien and K. Schulze. *Monatsh. Seide Kunstseide*, 1935, V. 40, P. 288–90, 335–40, 381–6.

A review and a discussion of a theory of dyeing based on the relation between the state of aggregation of the dye and the concn. of electrolytes in the bath. (From *C. A.*, 1935, V. 29, Col. 7662.) (W)

SUBSTANTIVE DYEING: THEORY OF. II. INFLUENCE OF CATIONS OF DIFFERENT VALENCE ON THE DEGREE OF DISPERSION OF SUBSTANTIVE DYES AND ON THEIR ADSORPTION BY COTTON. N. A. Krotova. *Kolloid-Z.*, 1935, V. 72, P. 345–53; cf. *C. A.*, 1935, V. 29, Col. 348, 8337. (W)

SULFUR DYESTUFFS: SOME RECENT DEVELOPMENTS IN THE APPLICATION OF. John L. Crist. *Am. Dye. Rptr.*, Jan. 13, 1936, P. 11.

Some recent developments in the application of sulfur dyestuffs are presented under the following headings: (1) Standing vs. single bath methods; (2) The proper functioning of exhausting materials; (3) Additive ingredients to assist reduction; (4) Subsequent processing; (5) Tendering; (6) Selection of types for compounded shades. (C)

SULPHATED AND SULPHONATED FATTY ALCOHOLS: WETTING POWER AND DETERGENT ACTION. J. G. Evans. *J. Soc. Dyers and Col.*, 1935, V. 51, P. 233–40; *J. T. I.*, Oct. 1935, P. A505. (C)

SYNTHETIC DETERGENTS: DISPERSING ACTION ON CALCIUM SOAPS. K. Lindner. *Leipz. Monats. Text. Ind.*, 1935, V. 50, P. 120–2, 145–6; *J. T. I.*, Oct. 1935, P. A505. (C)

TEXTILE AIDS, THEIR DEVELOPMENT AND PROPERTIES: MODERN. Fritz Ohl. *Spinner u. Weber*, 1934, V. 52, No. 49, P. 9–14.

A review is given of the uses of Turkey-red oils, highly sulfonated oils, fatty alcs., fatty alc. sulfonates, condensation products of fatty acids with low-mol. sulfo acids, combination products of fatty alc. compds. with solvents for fats, etc. (From *C. A.*, 1935, V. 29, Col. 8340.) (W)

TEXTILE USES OF UREA AND THIOUREA. R. A. Hague. *Tex. Col.*, 1935, V. 57, P. 538.

The uses of urea in textile printing and of thiourea in dyeing, particularly acetate rayon, to improve the color fastness, are discussed. (From *C. A.*, 1935, V. 29, Col. 7085.) (W)

TITANIUM COMPOUNDS: APPLICATION IN THE RAYON INDUSTRY. M. Deribere. *Rusta*, 1935, V. 10, P. 147–53, 227–31, 297–9, 365–7, 435–41, 513–7, 587–9.

A general account is given of the use of titanium dioxide for the delustering of rayon, the behaviour of the delustered rayon in weaving and dyeing processes, the detection of titanium in textile materials, the affinity of titanic acid for dyes, the use of titanium oxide in printing, and the use of titanium compounds in stripping dyed goods, in fireproofing and in analysis. (From *J. T. I.*, Dec. 1935, P. A629.) (C)

VAT DYES OF THE BENZANTHRONE SERIES. XI. FORMATION AND SEPARATION OF THE ISOMERIC DICHLOROBENZANTHRONES. T. Maki and Y. Nagai. *J. Soc. Chem. Ind., Japan* 38, Suppl. binding, 1935, P. 487–9; cf. *C. A.*, 1934, V. 28, Col. 5435; 1935, V. 29, Col. 8337. (W)

IV. RESEARCH METHODS AND APPARATUS

PROTEINS: HYDRATION AND DENATURATION; X-RAY STUDY. W. T. Astbury and R. Lomax. *J. Chem. Soc.*, 1935, P. 846–51.

X-ray photographs are shown of various proteins in the normal, hydrated and denatured states. The evidence afforded supports the theory that a fully extended polypeptide chain is characterized by two principal side spacings approximately at right angles to each other, one arising from the effective thickness of the "backbone" of the chain, and the other from the average lateral extension of the side chains standing out from the amino-acid residues. These two spacings appear to represent the two principal modes of linkage of neighboring protein chains. (From *J. T. I.*, Oct. 1935, P. A535.) (C)

RAYON FABRICS: ANALYSIS OF. J. Klinger. *Kunstseide*, 1935, V. 17, P. 100–3.

The use of the microscope for detg. various characteristics of fibres in rayon fabrics is described. (From *C. A.*, 1935, V. 29, Col. 7665.) (W)

RAYON FILAMENTS: SWELLING AND EXTENSION. W. Weltzien and J. Buchkremer. *Monats. Seide u. Kunstseide,* 1935, V. 40, P. 183–6, 259–62.

An improved form of apparatus for measuring the increase in length of rayon filaments on immersion in water or other liquids is described. (From *J. T. I.*, Oct. 1935, P. A522.) (C)

RUBBING: MACHINE FOR TESTING FASTNESS TO. C. O. M. Steward. *Dyer,* 1935, V. 73, P. 499–500; *J. T. I.*, Oct. 1935, P. A527.

The yarn or cloth is wound on a drum which rotates at 340 r.p.m. At a fixed distance the stationary rubbing shoe, covered with white cloth, is brought into rubbing contact for 12 sec. A rectangular mark is thus produced on the white cloth. The proposed standard rubbing test includes scouring the hank, rubbing the yarn on the machine, and judging the intensity of the rub with a Lovibond tintometer or an opacity meter. (From *C. A.*, 1935, V. 29, Col. 6767.) (W)

WOOL STAPLE: MEASUREMENT OF. Max Matthes. *Monatschr. Textil-Ind.,* Trade Issue II, 1935, V. 50, P. 41–6.

A crit. exptl. examination of various methods reported in the literature showed that only the methods of Cobb and Johannsen-Zweigle are of sufficient scientific accuracy. (From *C. A.*, 1935, V. 29, Col. 7663.) (W)

PORTABLE CHEMICAL BALANCE. H. Lloyd. *J. Sci. Instr.,* July 1935, P. 222–4.

Constructional details are given of a simple design of miniature spring balance for weighing out small samples of material required for analysis. The instrument is portable, permits rapid weighings to be made and has proved entirely satisfactory in use. (From *Science Abs., Sept.* 1935, Col. 3304.) (X)